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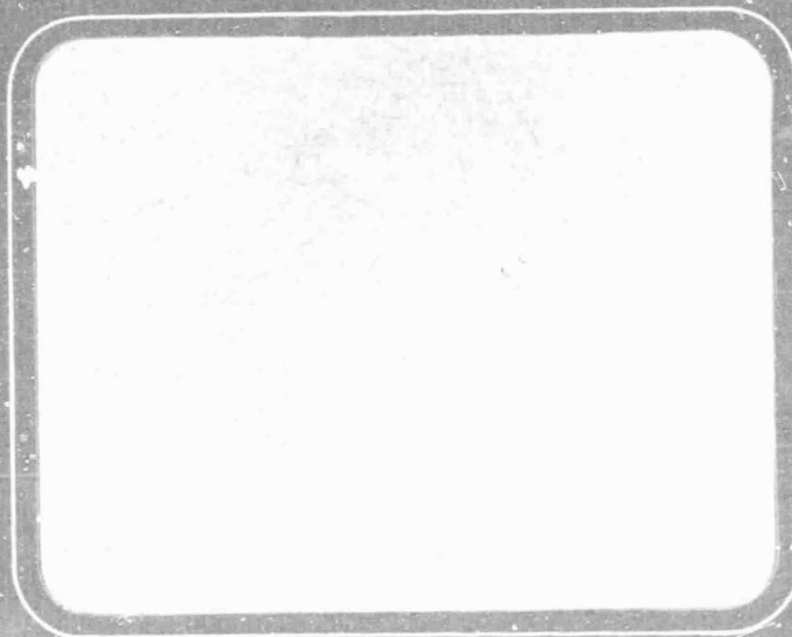
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# Report



FINAL REPORT

on

SEASAT DEMONSTRATION EXPERIMENTS WITH  
THE OFFSHORE OIL, GAS AND MINING INDUSTRIES

(Report No. BCL-OA-TFR-79-6)

by

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#### FOREWORD

This study was performed by Battelle's Columbus Laboratories (BCL) as Task No. 7 under Contract No. NASw-2800, for the NASA Office of Space and Terrestrial Applications (OSTA). Dr. A. C. Robinson is the Battelle Project Manager for the contract. A. George Mourad was the task leader for this study. The NASA OSTA Technical Monitor was Douglas R. Broome.



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SEASAT DEMONSTRATION EXPERIMENTS  
WITH THE OFFSHORE OIL, GAS AND MINING INDUSTRIES

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INTRODUCTION

This report covers the activities performed by Battelle concerning the NASA Seasat Commercial Demonstration Program. It describes several experiments involving the offshore oil, gas and mining industries for the purpose of demonstrating the capabilities of the Seasat satellite and the utility of the data acquired to various ocean activities.

The Battelle role with Seasat has been to assist NASA in developing and coordinating experiments in which organizations in the offshore industry will use and evaluate data from Seasat, the first satellite designed to provide global sensing of the ocean surface. Participation of a number of such organizations involved in oil and gas exploration and production and deep ocean mining was solicited. Eight experiments were defined, involving 16 sponsors. Battelle secured the cooperation from the offshore industry and participated with the experiment groups and with NASA in preparing the experiment plans and getting the plans approved by management in each participating organization. Battelle also contributed significantly to development of the specifications for the user data delivery system.

In June 1978 the satellite was launched, and began producing data within hours. A data record of about 3 months was collected before the satellite experienced a massive failure in the power supply in October 1978. Although Seasat was no longer able to transmit data, all the experiment groups in the offshore oil, gas and mining industries decided to remain in the program, and it now appears that most of the original program objectives can be met. Battelle assisted NASA in reworking the experiment plans in recognition of the altered circumstances. Some users will work primarily with data taken during the period in which the satellite was operating. Other users will work primarily with data transmitted in near-real time from the U.S.

Navy Fleet Numerical Weather Central (FNWC) in Monterey, CA. Only the final modified experiment plans will be described in this report.

## BACKGROUND

### Seasat/Industry Benefits

Preliminary estimates of Seasat benefits were made during 1974-1975.<sup>(1)\*</sup> In the case of offshore oil and gas, these showed that benefits during the years 1985 to 2000 would range from \$214 to \$344 million (1975 dollars). In addition, \$96 to \$288 million should accrue to arctic operations, most of which are associated with the oil and gas industries. No estimates were made in that study for the deep ocean mining industry, but the benefits should be substantial.

In economic terms, these industries are highly significant. The offshore oil and gas industry represents the largest single economic activity in the world's oceans.<sup>(2)</sup> The value to the U.S. alone was estimated at \$3.2 billion in 1973, with projections of \$18.9 billion by the year 2000. Ocean mining activities are projected to reach \$2.5 billion by the year 2000; the U.S. mining industry alone will have spent some \$300 million before the first commercial operations begin.<sup>(3)</sup>

### Description of Seasat

Seasat carried five instruments used for ocean monitoring. These are a compressed pulse altimeter, a microwave scatterometer, a synthetic aperture radar (SAR), a scanning multichannel microwave radiometer (SMMR) and a visible and infrared radiometer (V/IR). Figure 1 illustrates the coverage provided by each of these sensors. A brief description of these instruments, their applications, and their capabilities follows. For detailed information on instrument capabilities for measuring geophysical and oceanographic parameters, and the user requirements, see publications by Nagler and McCandless<sup>(4)</sup> and Apel and Siry<sup>(5)</sup>.

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\*References, denoted by superscript numbers, are at end of text.



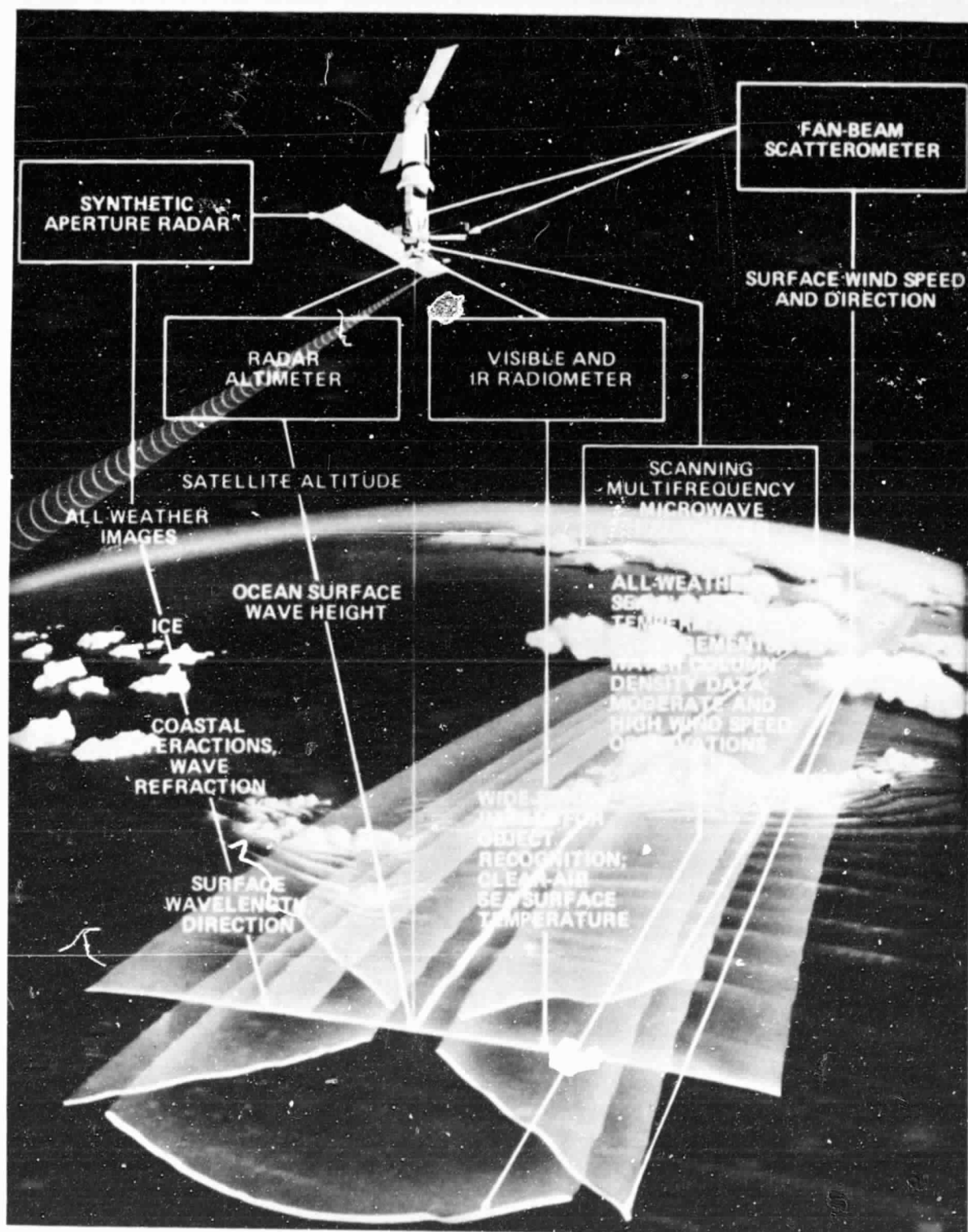


FIGURE 1. SENSOR COVERAGE



## Instruments

Radar Altimeter. The radar altimeter has two functions. First, it monitors the average wave height from 1 to 20 m to within 0.5 m, or 10 percent accuracy along a narrow (1.6 to 12 km) swath directly below the satellite path. This is done by measuring the broadening of the altimeter echo caused by increased surface wave action. Second, by measuring changes in the satellite-to-sea-surface distance to within  $\pm 10$  cm (RMS), it detects variations in mean sea level (geoid), tides, storm surges, and currents. The radar altimeter has a 3 nanosecond pulse width and operates at a frequency of 13.5 GHz (2.2-cm wavelength). The SEASAT-1 altimeter is an improved version of those flown on Skylab and GEOS-3.

Radar Scatterometer. The radar scatterometer acts as an anemometer for measurement of surface wind speeds from 4 to 26 m/sec within 2 m/sec, or 10 percent (whichever is larger), and wind direction within 20 degrees. The instrument covers two 500 km swaths, one on each side of nadir. Individual wind magnitude determinations cover cells of about 50 km on the sea surface. The scatterometer operates at 14.595 GHz (2.1-cm wavelength) and consists of four inclined, side-looking, microwave beams displaced 25 degrees from the nadir. On each side there are two narrow fan beams placed 45 degrees forward and back, allowing two looks at each piece of the ocean separated by 90 degrees for determining wind direction. The signal strength of the reflected energy increases with the increase in wind-driven waves, which can be used to compute wind speed. The Seasat scatterometer is an improved version of the Skylab instrument, with global coverage (95 percent) possible every 36 hours.

Synthetic Aperture Radar. The SAR is an instrument which was not previously flown in a satellite. It provides all-weather imagery of ocean features, i.e., ice fields, icebergs and leads, slicks, wave and current patterns, and coastal conditions. Resolution is 25 meters over a 100-km swath, 230 to 330 km off nadir. The SAR, operating at 1.275 GHz (22-cm wavelength), is capable of penetrating clouds and nominal rain. It has its own data recording system and a very high data rate. Because of this, it was operated

only while within line of sight of those tracking stations that are equipped to receive and record its data. Conversion of the radar measurements to imagery was not provided in real time.

Microwave Radiometer. The SMMR is a passive system which measures the incident electromagnetic radiation in a selected region of the spectrum. It operates on five frequencies (6.6, 10.7, 18.0, 21.0, and 37.0 GHz) and serves four functions:

- (1) Measures surface temperatures to within 1° C by measuring the microwave brightness of the surface
- (2) Measures foam brightness, which can, in turn, be converted into a measurement of intermediate to high (50 m/sec) wind speed (no direction measurement)
- (3) Detects ice age, extent, concentration and dynamics
- (4) Provides atmospheric correction data to the radar altimeter and scatterometer.

This instrument has a swath of 600 km off nadir. Similar instruments were flown on Skylab, Nimbus-5, and Nimbus-6. The SMMR was also flown on Nimbus-G, which provided global coverage every 72 hours. The Seasat-1 SMMR provided global coverage (95 percent) every 36 hours.

Visible and Infrared Radiometer. The V/IR provides clear-weather surface temperature data, cloud coverage patterns, and corroborative images of ocean and coastal features with a resolution of 3 km (visible) and 5 km (IR) over a swath of 1500 km centered on nadir. Wavelengths are 0.49 to 0.94  $\mu\text{m}$  (visible) and 10.5 to 12.5  $\mu\text{m}$  (IR). This instrument is a modified version of those flown on the NOAA operational satellites.

#### Data System

The Seasat data system covers all data processing elements from remote sensing of ocean phenomena through collection and storage on-board the satellite, transmission to the earth for storage, conversion, and merging of the various sensor data, blending with supporting external data, and delivery to the ultimate users for data analysis, interpretation, and utilization.

Data from the altimeter, scatterometer, SMMR and V/IR radiometer were recorded in the satellite and played back when the satellite was over the tracking stations supporting Seasat. The data from these instruments are being processed into geophysical units at the Jet Propulsion Laboratory. Original plans were to transmit near-real-time data to the user requiring such data. As noted, data from the imaging radar were not recorded but were transmitted only to specific tracking stations. Some of these data were processed at the Jet Propulsion Laboratory and shipped to users.

Seasat utilized the following six major subsystems to accomplish these data processing services: (1) satellite data subsystem; (2) ground tracking and data acquisition subsystem; (3) mission operations and control subsystem; (4) project data processing subsystem; (5) SAR data processing subsystem; and (6) user data subsystem.

#### Data Products

As a broad spectrum of user applications was anticipated, Seasat data products were designed to serve a wide variety of users in a variety of forms. Data were to be provided either in near-real time or historically. The real-time data system, however, did not become operational during the short life of Seasat.

Near-Real-Time Data. The near-real-time data were to include environmental data parameters such as surface winds, waves, and temperatures; temperature maps and wind field maps; and forecasting products for weather, waves, ice, and hurricanes. Four of the Seasat instruments (altimeter, scatterometer, SMMR and V/IR) are applicable for generating the above data. In some cases, such as obtaining accurate temperature data, output from all four instruments was required. It was expected that the near-real-time data (0 to 6 hours) would be transmitted from Seasat-1 to the Fairbanks, Alaska, tracking station which, in turn, would retransmit them to FNWC. FNWC was to process the data into geophysical units and incorporate them into their data product for distribution to appropriate organizations.

Non-Real-Time (Historical) Data. Historical data can be grouped as SAR and non-SAR data. The non-SAR data include wave heights, wind field, ice coverage, currents, and temperature. These data were transmitted from Seasat to several tracking stations and were collected at NASA/GSFC mission operations. The data were then transmitted from GSFC through the unified S-band to JPL where they were converted to geophysical quantities and distributed to the experiment participants.

As noted above, SAR data could not be recorded on-board Seasat because of the high data rate ( $20 \times 10^6$  bits/sec). SAR data were collected for specific areas over the U.S. and Canada on a limited basis. Limited SAR data were taken during the life of Seasat. Only special tracking stations were equipped to receive these data and in turn send them to JPL. JPL converted part of the data into imagery and mailed them to the participating experiment team members.

#### Mission Objectives Achievability

The main objective of the Seasat project was the proof of the concept of microwave remote sensing of the world's oceans from a satellite platform. In order to accomplish this goal, a substantial set of satellite and corresponding surface truth data covering a reasonable range in wind and sea conditions was required. Fortunately, during 3 months of operation, the satellite returned a unique and important set of data regarding the earth's oceans. The first extensive correlation and evaluation of Seasat and surface truth data was conducted at the Gulf of Alaska Seasat Experiment (GOASEX) Workshop, which was held at the Jet Propulsion Laboratory (JPL) on January 22-26, 1979. Experiment teams established for all the sensors met and conducted their analyses; these teams are responsible for calibration and validation of Seasat systems, algorithms, and data. In all, 15 Seasat passes over the Gulf of Alaska area occurring during 14, 16, 17, 19 and 25 September were selected for analysis during this workshop. Also, some passes were analyzed that occurred during Hurricane Fico.

GOASEX was a concerted, high quality and comprehensive surface truth collection effort on the part of many organizations including several NOAA



laboratories, several NASA Centers, Canadian organizations, the Naval Research Laboratory, the University of Alaska and the U.S. Geological Survey. Data were collected during July and August 1978 under some 60 satellite passes using several oceanographic ships, weather ships, data buoys and aircraft.

The preliminary results obtained from the GOASEX Workshop proved that most of the Seasat objectives and specifications for sensor accuracies and spatial resolutions have been or will be met with extreme success. According to the GOASEX Altimeter Experiment Team report, the results provided ample evidence that the radar altimeter, having undergone development through three separate earth orbit missions (Skylab, GEOS-3, Seasat), has reached a level of precision and accuracy that now permits the use of the data for important quantitative oceanographic investigations and practical applications.<sup>(6)</sup> Once we have similar experience with the other sensors and algorithms, it appears that satellite microwave systems would, in the future, be capable of collecting oceanographic and environmental data with sufficient accuracy that the collection of surface measurements would be minimized considerably.

#### OFFSHORE OIL, GAS AND MINING INDUSTRIES EXPERIMENTS

Throughout the Seasat program, NASA has devoted substantial effort to getting potential users involved. From the early conceptual phases to the present, there has been in existence a users' committee, consisting of representatives from government, the academic community, and industry. This committee has been a major influence in bringing the Seasat program to its present configuration.

Although Seasat-1 is a "proof-of-concept" satellite, NASA included as one of its goals the actual demonstration of the utility of Seasat data to operational users. To accomplish this, NASA set up experimental programs with selected potential user industries. Through these demonstrations, NASA plans to transfer its technology directly to the user, who, in turn, is expected to provide evaluation of Seasat capability and its impact on its operations.

Numerous contacts were made with industrial organizations, and 22 experiment plans were generated in the following areas: marine resources, marine transportation, and fisheries and other biotic resources. Battelle then

coordinated, for NASA, eight experiments with several companies and organizations representing the oil, gas and mining industries. Table 1 identifies these eight experiments and the participants. Figure 2 shows the approximate geographic locations of the eight experiments.

During the operation of Seasat, these organizations were to investigate the usefulness of the data to various applications. These applications included:

- (1) Improvements in weather and wave forecasts
- (2) Improved knowledge of past winds as well as wave statistics for setting design criteria and for planning operations, particularly in frontier and remote areas where data are virtually nonexistent
- (3) Monitoring ice formation, breakup and movement in arctic regions.

These investigations are conducted jointly by NASA and the participating organizations. NASA is to provide appropriate Seasat data and the industry will compare them with their own collected sea truth observations, estimate the potential benefits to offshore operations, and report the results of data interpretation and analysis.

#### Objectives

The original objectives of these experiments were to:

- (1) Assist in verification of Seasat sensor accuracy and capability
- (2) Permit potential users to evaluate the practical value of the data in their activities
- (3) Begin the process of transferring the technology to the user community
- (4) Assist in developing the requirements for an operational system for monitoring the oceans from space.

#### Approach Used and Results Obtained

The approach used to secure the participation of these offshore industries involved the following steps.

TABLE 1. SUMMARY OF SEASAT EXPERIMENTS WITH THE OFFSHORE OIL, GAS AND MINING INDUSTRIES

ASVT NO./EXPERIMENT TITLE	COMPANY/ORGANIZATION	REPRESENTATIVE
(1) Beaufort Sea Oil, Gas and Arctic Operations	Gulf Canada Ltd.	B. Wright
	Esso Resources Canada Ltd.	G. Spedding
	Canadian Marine Drilling	B. Mercer/G. Davis
(2) Labrador Sea Oil, Gas and Sea Ice	Total Eastcan Exploration Ltd.	M. Jozan/ D. Berenger
	Esso Resources Canada Ltd.	G. Spedding
(3) Gulf of Mexico Pipelines	American Gas Association	R. J. Simmons
(4) U.S. East Coast Offshore Oil and Gas	CONOCO	F. Rose/ J. Boujnoch
(5) Worldwide Offshore Drilling and Production Operations	Getty Oil Co.	H. DeMirjian/ P. Wybro
(6) Equatorial East Pacific Ocean Mining	Deepsea Ventures, Inc.	W. Siapno
	Kennecott Exploration, Inc.	A. Steen
	INCO Limited	J. L. Shaw
	Ocean Minerals Co.	F. T. Lovorn
(7) Bering Sea Ice Project*	Oceanographic Services, Inc.	D. C. Eckert
(8) North Sea Oil and Gas	CONOCO	F. Rose
	Union Oil Research	M. Utt

\*This experiment was modified by NASA/LeRC to provide aircraft data instead of SAR for ice studies. There was no ice in the Bering Sea during the life of Seasat to verify the usefulness of the SAR.

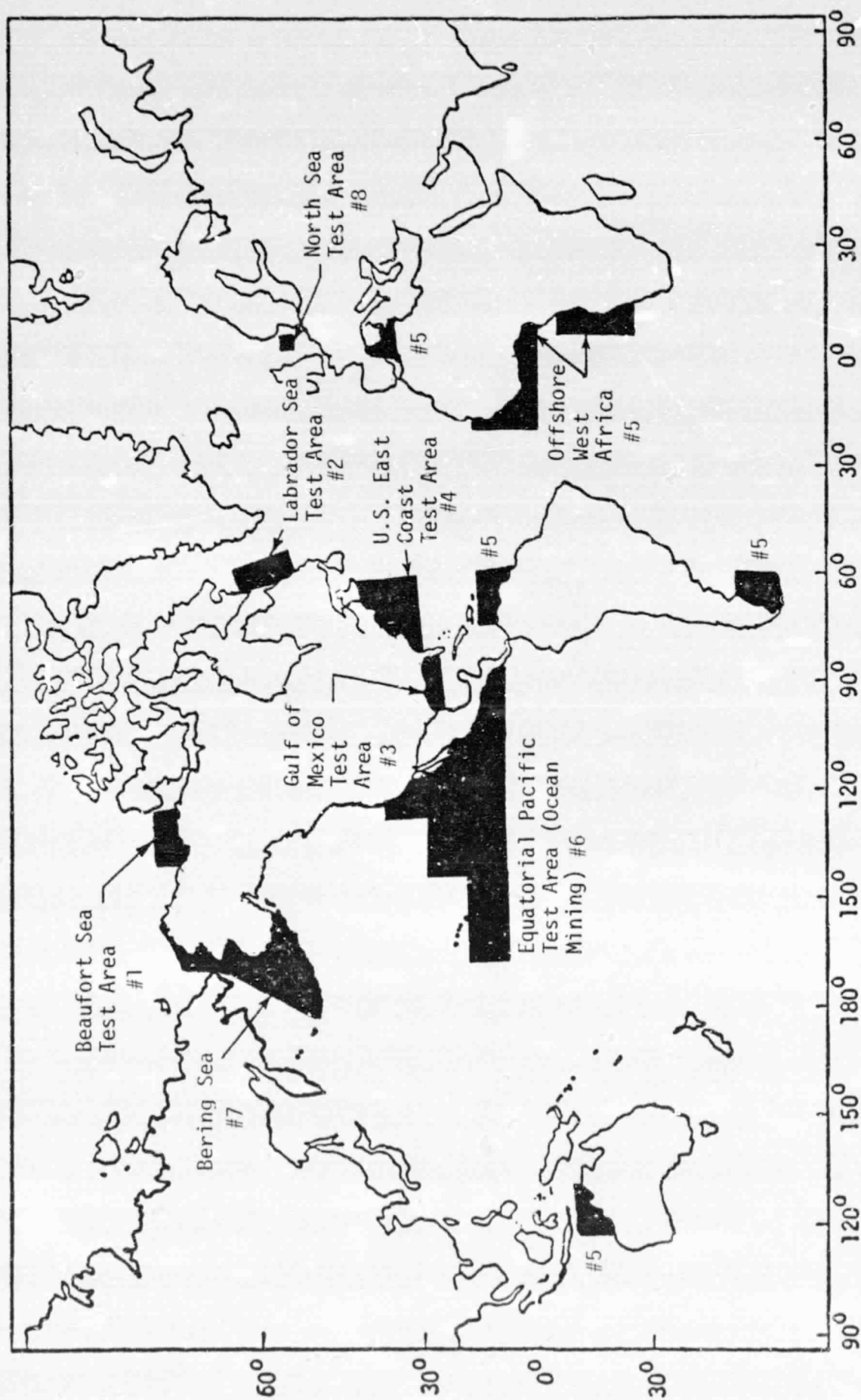


FIGURE 2. APPROXIMATE LOCATIONS OF THE OFFSHORE OIL, GAS AND MINING INDUSTRIES EXPERIMENTS



Step 1. Develop Seasat application areas of interest to offshore oil, gas and mining industries. These applications included the establishment of satellite environmental data banks to be used in statistical studies for determining maximum occurrences and to provide criteria for design of fixed structures and for long-term operational planning.

Step 2. Identify individual industry leaders and organizations and obtain their expressed interest in participating in cooperative experiments with NASA. This was accomplished through long-time established contacts among Battelle and industry representatives. Meetings and oral presentations were made to numerous companies and associations, the result of which culminated in selecting the present eight experiments.

Step 3. Develop initial experiment plans and Memoranda of Understanding (MOU) for signature by industry and NASA representatives. In our work with representatives of the industries to define problem areas and determine how Seasat data could help in their solutions, several sets of parameters and test locations were established. A working document entitled "Preliminary Plan for A Seasat-A Verification Experiment" was drafted by Battelle and submitted to representatives from the industry and NASA on April 15, 1977. This document contained the initial experiment project plans including individual experiments, proposed schedules and milestones. Soon after this document was disseminated, work started with NASA on developing an initial MOU that could be satisfactory for both NASA and industry. Once the industry data requirements were defined, work was initiated at JPL on defining the data distribution system, its formats, equipment and communication requirements. Battelle assisted JPL in this area. The work with JPL resulted in the publishing of several documents by JPL, of which the final one was called "Seasat ASVT Commercial Demonstration Experiments User Requirements Document", by Elliot M. Gold, June 1979. Also, Battelle supported FNWC and NASA in defining the initial requirements for the data communication network, including user terminals, telephone lines, computer interface and estimated costs.

Step 4. Develop final experiment plans including MOU's. The initial experiment plans and MOU's developed in Step 3 were redrafted, including most of the comments received by all concerned. Then meetings were set up with each experiment representative(s) to discuss and finalize experiment plans and MOU's; the final experiment plans are included later in this report. These present details for each experiment on: experiment location and parameters, objectives, potential benefits, approach, analysis procedures, data requirements and formats, surface truth data available, schedules, milestones and reporting procedures.

Step 5. Coordination of experiments. This included the coordination of acquisition and distribution of Seasat data, technical assistance required by industry participants to understand Seasat sensors and their coverage as well as their applications; providing assistance and arranging for workshops and meetings, facilitating the exchange of information among companies, and promoting technology transfer as much as possible; and monitoring the quality of experimental results being obtained and suggesting means for improvement, if required. Two publications that resulted from this work and are representative of the technology transfer aspect of this task are included in the Appendix found at the end of this report.

#### Activities Conducted After Seasat Failure

On October 10, 1978, Seasat experienced severe power difficulties which led to its failure. The question then arose as to what to do about the commercial Seasat experiments since the main interest in the real-time data distribution system was no longer valid. A meeting was held at JPL on October 31 and November 1, 1978, and representatives of these experiments attended. During that meeting, JPL project personnel showed samples of Seasat results that had been taken earlier and reviewed the status of processing and algorithm development. Although these results were preliminary, they were impressive, particularly those from the altimeter and the synthetic aperture radar (SAR). Also, there appeared to be about 99 days of Seasat data that could be processed for and analyzed by the experimenters. Personnel from FNWC then

discussed the status of their real-time data distribution system and how they intend to use data from Nimbus in the system; Nimbus carries the same type of SMMR instrument as that on Seasat. The meeting was then dissolved into three working groups that were chaired by industry representatives. Frank Rose of CONOCO chaired the group for the oil, gas and mining experiments. Each group then reviewed the status and objectives of their experiments and the future direction that should be followed, particularly whether or not to continue their involvement in the program. The results of these reviews were presented on the second day, when all groups reassembled into one for discussion of their deliberations.

The consensus of all representatives who attended the meeting was that the experiments should be continued, with perhaps some modification of objectives, for the following reasons:

- (1) Seasat-1, being a proof-of-concept program, has a reasonable volume of data that could be utilized by the industrial participants on a non-real-time basis to prove the concept.
- (2) The real-time distribution system set up at FNWC could still be validated using their products. Other satellite data such as those from the Nimbus-G SMMR instrument could be incorporated in FNWC products, thus providing further validation of a real-time satellite data distribution system.
- (3) The industry has acquired surface truth data during the life of Seasat that are sufficient to provide the baseline for validation and evaluation.
- (4) The industrial efforts already expended on these experiments are appreciable, and have reached to the level of upper management (most of the MOU's were signed by the presidents or vice presidents of the various companies involved). Any disruption of the experiments at this time would risk alienation of these companies from any future support of satellite programs, especially when the industry representatives believe that there are sufficient Seasat data to be evaluated.
- (5) The representatives noted that their involvement with the Seasat program acclimated them to the use of satellite data, and they

would like to have access to existing satellite data such as those from GEOS-3. They asked that NASA make a catalog of GEOS-3 ocean-related data available to them so they can select enough data to provide a baseline for evaluation in their planning of activities and design of facilities.

The results of discussions from this meeting were presented to NASA Headquarters program management staff, who agreed to continue, at some level, the commercial experiments.

On the basis of the above premises, the program was revitalized and visits were made by personnel from JPL and Battelle to the offices of the experiment representatives. Discussions resulted in modification and amendment of all project plans for the experiments. The new approach for each of the experiments was adopted as follows:

- (1) Conduct analysis of case studies on the Seasat data (non-real time) to validate sensor accuracy and data utility, as was originally planned prior to the failure of Seasat, but with a lesser data base.
- (2) For those who require real-time data in addition to the non-real-time data, conduct evaluation of a real-time data distribution system using Fleet Numerical Weather Central (FNWC) products and forecasts and some Nimbus satellite data (as if they were Seasat data). Nimbus has a Scanning Multichannel Microwave Radiometer (SMMR) similar to the one on Seasat which will provide data on winds and sea surface temperature. The emphasis in evaluation here is on the capability, timeliness and effectiveness of such a data distribution system in anticipation of a future operational satellite program.

Briefly, Experiment Nos. 1 through 6 will require both real-time FNWC data and Seasat non-real-time data. Experiment No. 7 requires aircraft data only, and Experiment No. 8 requires only non-real-time Seasat data. A summary of each experiment case study (use of Seasat non-real-time data) is presented next.



### Summary of Case Studies

#### Beaufort Sea Experiment (ASVT No. 1)

The objective of this case study is to evaluate microwave data obtained from Seasat as an aid to improving oil and gas exploration operations in the ice-infested waters of the Beaufort Sea. This case study involved Seasat Geophysical Data Records (GDRs) (primarily waves and winds) and Synthetic Aperture Radar (SAR) imagery, with the primary emphasis on SAR. Three periods are selected for analysis between July and September to coincide with ice movements and with the collection of surface truth data. Surface truth data were collected from three drillships, artificial ice islands and aircraft. Analysis of the data will be undertaken jointly by all the participants. The participants further plan to conduct special workshops on data analysis and evaluation with other participants from Experiment Nos. 2 and 22. Based on the results of comparison and analysis, assessment will be made of the utility of Seasat-type data and their benefits to offshore oil and gas exploration in arctic operations and environment.

#### Labrador Sea Experiment (ASVT No. 2)

The objective of this case study is to verify Seasat data with industry-collected surface truth data for oceanographic, meteorologic and sea ice monitoring and to assess the utility and benefits of Seasat data to offshore exploration, drilling, design and production operations. Data requirements include SAR imagery and GDRs (waves and winds). Surface truth data were collected using a drillship, a buoy, two oceanographic ship cruises, and aircraft; ice observations were made within 30 km of the drillship. These data will serve as the basis for comparison analysis and evaluation of Seasat data and their utility in various stages of oil operations. The Atmospheric Environmental Services (AES) of Canada (ASVT No. 22) will cooperate in providing forecasts using Seasat data for the Labrador Sea participants. Evaluation of such forecasts in comparison with past ones will probably be made during a planned workshop involving participants from all three experiments (Nos. 1, 2,

and 22). Based on the results of evaluations, assessment will be made of the utility and benefits from Seasat-type data in future operational programs.

#### Gulf of Mexico Experiment (ASVT No. 3)

The objective of the Gulf of Mexico case study is to assess the utility of Seasat-type data to improve design criteria for pipelines, correlate the effect of satellite data with subsurface conditions, and determine the accuracy of predicting severe storms. Documented times of significant weather episodes in the Gulf of Mexico during the Summer of 1978 are available for this experiment. During that time Vega Weather Service, Inc., was under contract to provide one of the American Gas Association (AGA) member companies with forecasts and advisory services. Detailed records are available. Seasat GDRs will be used to formulate forecasts on selected days where severe conditions existed in the Gulf of Mexico. These forecasts will then be compared with existing records for that time. In addition, various platform operators have been asked to provide any surface truth data they may have collected during the life of Seasat. These data will be used to validate sensor accuracy and quality. Based on the results of comparison, evaluation will be made as to data utility and potential benefits that could be obtained from a future operational satellite system.

#### U.S. East Coast Experiment (ASVT No. 4)

The objective of this case study is to determine the applicability and benefit of Seasat-type data for establishing design and operational criteria for offshore facilities. CONOCO has environmental data taken during the life of Seasat on drillships operating in two locations:

- (1) Off the southwest coast of Sicily
- (2) Off the U.S. East Coast in the Baltimore Canyon.

CONOCO has also obtained and evaluated GEOS-3 data for location (1) above. CONOCO will obtain from NASA Seasat GDRs for both locations (1) and (2) and four SAR passes for location (2). CONOCO will use these data by validating sensor capabilities against their surface truth data and evaluate the fore-

casting value of the sensor data by using GDRs as input to forecasts. The resulting forecasts will be compared with existing (during the Summer of 1978) forecasts. Based on these comparisons, the data will be assessed in terms of (1) meeting the experiment objectives and (2) potential benefits that could be derived, provided that an operational satellite system exists in the future.

Worldwide Offshore Drilling and Production  
Operations Experiment (ASVT No. 5)

The objective of this case study is to assess the utility of Seasat-type data for offshore oil and gas drilling and production operations. Getty Oil Company (as operator for several other companies) has available detailed environmental data (winds, waves, pressure, temperature, currents) measured on the "Discoverer Seven Seas" drillship during July to October 1978 (during the life of Seasat) in two areas:

- (1) Off Ibiza Marino (Spain) from July 1 to July 23
- (2) The Straits of Ontranto (Italy) from August 3 to October 1.

The Seasat GDRs to be received from NASA will be used in Getty's Seasat data evaluation case study to:

- (1) Validate sensor capacity in comparing with surface truth
- (2) Evaluate the forecasting value of the sensor data by comparing them with forecasting reports previously generated by Getty
- (3) Assess the use of Seasat data in design (build an environmental data base)
- (4) Determine potential benefits that can be accrued based on a future operational satellite system that could provide Seasat-type data.

Pacific Ocean Mining Experiment (ASVT No. 6)

The objective of this case study is to assess Seasat data utility for ocean mining design, exploration and operations. Two of the companies (Deepsea Ventures and Ocean Minerals) were operating during the life of Seasat and have available environmental data taken from their mining ships. These data will be used for comparison with Seasat GDRs to determine the applicability and benefits of Seasat data for affecting decision processes during ocean

mining design, exploration and operations. During the life of Seasat, near-record hurricanes occurred in the Pacific Ocean, affecting the mining areas of interest. Seasat data (primarily waves and winds) will serve as excellent input for establishing a severe weather forecasting scenario. The intent of the case study is to provide the meteorological scenario from whatever source data may be available and to determine the enhancement that is possible by adding Seasat data. In this way, parametric evaluation of satellite-collected information of mid-ocean areas would be readily understandable. Seasat data will be first validated against surface truth and then analyzed; environmental forecasts will be prepared in hindsight. These forecasts will be compared with the results of the actual forecasts and conditions that existed in the past.

#### Bering Sea Experiment (ASVT No. 7)

The main interest of the Alaska Oil and Gas Association (AOGA) in this experiment was to evaluate the use of SAR data for ice studies. Since, during the life of Seasat, there were no ice conditions in the Bering Sea, Seasat data would not be applicable. However, NASA/LeRC conducted ice measurements using microwave systems from aircraft in March of 1979 in the Bering Sea. The resulting aircraft data, similar to those from Seasat, will be utilized by industry in their analysis and evaluation.

#### North Sea Experiment (ASVT No. 8)

The objective of the North Sea case study is to determine the feasibility of using Seasat-type data for improving on design of structures and assessing data utility for daily operations. During the life of Seasat, surface truth data were measured and collected from four instrumented ocean platforms/buoys. These data included winds, waves, temperature, atmospheric pressures and other environmental data. This case study will consist of analysis and validation of non-real-time data. First, the available Seasat GDRs (taken within a 100-km radius of each platform) on waves, winds and temperature will be analyzed; then, these data will be compared with weather

conditions known to exist at that time. A forecast analysis will be made to determine what could have happened had GDR data been available at that time. Finally, Seasat data will be compared with the collected surface truth data, and an evaluation made as to the utility of similar types of data available from future satellite programs. The primary interest of the companies is in a system that will show high waves and winds and how it could be used in improving weather forecasts and establishing a long-term data base to predict extreme environmental conditions.

#### Program Status and Preliminary Results

Regarding Seasat and related data for the case study analyses, JPL completed the processing of some 26 days of Seasat altimeter and wind data and mailed them between July and August of 1979 to the industry representatives for their use in the case studies. Also, sample SAR passes were mailed. In addition, data were requested from NASA/WFC regarding hurricane and storm catalogs, wave height comparisons and GEOS-3 altimeter data. The storm data catalogs and wave height comparisons were obtained and mailed to interested representatives. Industry representatives were pleased with the catalogs received, indicating that the catalogs would enhance their evaluation process of Seasat case studies as well as contribute to their overall collection and use of pertinent historical data that will aid in facility design and operational planning. GEOS-3 data are being processed at NASA Wallops and may become available during January 1980.

The real-time distribution system is viewed as most important for many experimenters. It finally became operational during September/October 1979. An important milestone was reached when a successful demonstration was made of the real-time data distribution system at the Navy FNWC facility in Monterey on August 14, 1979. Industrial representatives expressed their pleasure and renewed their earlier (prior to Seasat failure) enthusiasm concerning their participation in the Seasat commercial demonstration program. Most felt that the original objectives of their experiments may still be met. Some of them admitted that, after Seasat failure, they sat back and waited to see what might evolve. But now they are convinced that the system will be of use.

However, the degree of its usefulness remains to be evaluated by all those involved in the program.

Several industry members participated in the Seasat Colloquium which was held on October 29 - November 1, 1979 at Scripps Institute of Oceanography in San Diego, California. Three presentations were made by representatives of the offshore oil, gas and mining industry experiments. Although time and data samples were limited, the preliminary results were encouraging. The specific comments made regarding the significance of Seasat data and results are listed below:

- Most significant applications of Seasat data are for climatological studies and oceanographic statistics to use as a data base (data bank), particularly for frontier or remote areas of the world oceans where sometimes no data exist at all. Examples of such uses are for determining maximum-occurrence events, for design of structures and facilities and for planning operations. As such, they are excellent.
- The data are not yet useful for day-to-day operations or for analysis of individual storms because of the large scatter shown in the results, particularly in the wind field data.
- Wave height results showed better scatter than those for the wind field and thus might be useful in hindcast analysis of large storms. However, they still require improvement.
- The capability of the Seasat altimeter to measure ocean current positions, slopes and eddies is of importance, particularly in the summer where temperature gradients are not sufficient to be reflected from radiometer measurements.
- In general, the representatives, aware of the limited sample of data they had to work with, were reluctant to make final conclusions regarding the accuracy and utility of the data.
- There is apprehension in the industry about future satellite programs. For example, what is to happen from now until NOSS becomes available? Some other areas of concern include the lack of industry involvement in future plans, and the cost of large programs in comparison to the benefits.

### DETAILS OF SEASAT ASVT EXPERIMENT PLANS

The final amended versions of the eight experiment plans for the offshore oil, gas and mining industries are presented in this section. These versions are the ones for which company executives signed Memoranda of Understanding with NASA, thus authorizing the joint industry/NASA cooperative ventures. Each experiment plan is presented verbatim on the pages that follow.

### REFERENCES

- (1) "Seasat Economic Assessment", Vol. 1, Econ, Inc., Princeton, N.J., August 1975.
- (2) "Economic Value of Ocean Resources to the United States", National Ocean Policy Study, 93rd Congress, 2nd Session, December 1974.
- (3) Livesay, B. J., personal communication, April 1977.
- (4) Nagler, R. G., and McCandless, S. W., Jr., "Operational Oceanographic Satellites - Potentials for Oceanography, Climatology, Coastal Processes, and Ice", Jet Propulsion Laboratory, September 1975, p. 12.
- (5) Apel, J. R., and Siry, J. W., "The Earth and Ocean Physics Applications Program (EAPAP) - Ocean Dynamics Program", SEASAT-A Scientific Contributions, NASA, Washington, D.C., July 1974, pp. 139-172.
- (6) Tapley, B. D., et al., "Seasat Altimeter Calibration: Initial Results", Science, Vol. 204, No. 4400, 29 June 1979, pp 1410-1412.



BEAUFORT SEA OIL, GAS AND ARCTIC OPERATIONS

(ASVT EXPERIMENT 1)

NASA/GULF OIL CANADA LTD., CANADIAN MARINE  
DRILLING LTD. AND ESSO RESOURCES CANADA LTD.

COOPERATIVE EXPERIMENT PLAN

July 1978

AMENDMENT 1

MARCH 1979

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
Office of Space and Terrestrial Applications  
Washington, D. C. 20546



## EXPERIMENT SUMMARY

ASVT EXPERIMENT: No. 1

TITLE: Beaufort Sea Oil, Gas and Arctic Operations

EXPERIMENT REPRESENTATIVE/ORGANIZATION: (B. Wright) Gulf Oil Canada Ltd., 715-5th Avenue, S. W., Calgary, Alberta T2P 0N2, Canada. Telephone: (403) 268-4484; (B. Mercer/G. Davis) Canadian Marine Drilling Ltd. (CANMAR), P.O. Box 200, Calgary, Alberta T2P 2H8, Canada. Telephone: (403) 232-5550; (G. Spedding) Esso Resources Canada Ltd., 339-50th Avenue S. E., Calgary, Alberta T2G 2B3, Canada. Telephone: (403) 259-0335.

COORDINATOR: For U.S.: (A. George Mourad) Battelle's Columbus Laboratories, 505 King Avenue, Columbus, OH 43201. Telephone: (614) 424-5097; and (Dick Gedney) NASA/LaRC, 21000 Brookpark Rd., Cleveland, OH 44135. Telephone: (216) 433-4000, x209.

For Canada: (René Ramseier) Surveillance Satellite Project Office, Department of Energy, Mines and Resources, 580 Booth Street, Ottawa, Ontario K1A 0Y7, Canada. Telephone: (613) 995-9261.

EXPERIMENT LOCATION: Test area is bounded by coastline to 72°30'N and 125°-140°W. Supporting area for Nimbus-7 imagery is to include the entire Beaufort Sea to 169°W.

OBJECTIVE/PURPOSE: To evaluate active and passive microwave data obtained from Seasat and from the SURSAT project as an aid to improving oil and gas exploration operations in the ice-infested waters of the Beaufort Sea.

APPROACH: Pertinent Seasat data and products provided by NASA and Nimbus imagery and Convair 580 data provided by the SURSAT Office will be collected, analyzed and compared with the surface truth data obtained by the operating companies during the experiment. Based on the results of the comparison, assessment will be made of the utility of Seasat data and their benefits to offshore oil and gas and arctic operations.

DATA REQUIREMENTS: Only non-real-time data are required. These include (1) Seasat GDR products of H<sub>1</sub>/3, wind speed and direction and sea surface temperature, (2) SAR data: ten passes, and (3) Nimbus-7 imagery and Convair 580 data to be provided by the SURSAT Office.

DATA FORMAT AND FREQUENCY: GDR products on 9-track tapes; three copies of SAR imagery on film positives and CCTs of 10 percent of the imagery, whenever available; Nimbus imagery on film positives once every three days; Convair data, after they have been taken, on films and tables.

COMMUNICATIONS EQUIPMENT AND DATA DELIVERY: The participating companies will receive the non-real-time data by mail in Calgary, Alberta, Canada.

SURFACE TRUTH DATA: Data include ice observations from drillships, dredging barges, artificial islands and reconnaissance flights. Data to include aerial photographs, wind speed and direction, wave information, temperature, and laser profile data.

### Beaufort Sea Oil, Gas and Arctic Operations

This experiment is being conducted by three Canadian companies in cooperation with NASA for the purpose of evaluating the potential that Seasat and related satellite data have for affecting the decision processes that must routinely be made during their oil and gas exploration and production operations in the ice-infested waters of the southern Beaufort Sea. The ultimate benefits expected through the use of these ice reconnaissance data include enhancement of human safety and reduction of costs or losses in current and future operations.

The companies involved in the experiment are: Gulf Oil Canada Ltd., Esso Resources Canada Ltd., and Canadian Marine Drilling Ltd. The Canadian Surveillance Satellite (SURSAT) Project Office is the liaison for this experiment. Petroleum and natural gas permits have been issued for approximately 42 million acres of the southern Beaufort Sea. In view of the large acreage and the high costs per well, large expenditures are involved. The proposed test area covers the offshore area out to latitude 72°30' north between longitudes 125° to 140° west in the southern Beaufort Sea, as shown in Figure 1. Geographical landmarks are Cape Bathurst at the mouth of the Amundsen Gulf and the Alaskan-Yukon boundary as the western extremity. This area encompasses the continental shelf with water depths increasing to 6000 feet at the northern limits. Figure 2 shows the possible specific locations of the Seasat validation test sites. Supporting area for Nimbus-7 imagery is to include the entire Beaufort Sea to 169°W.

The Canadian companies currently have environmental data taken in 1978 from barges/dredging vessels, drillships, artificial ice islands, and aircraft operating in the Beaufort Sea test area that will be used to determine the utility of Seasat-type data and their benefits to offshore oil and gas exploration in arctic operations and environment. Since the Seasat satellite failed on 10 October 1978, any further satellite data needed will be obtained from Nimbus, and the data products will be distributed by the Navy's Fleet Numerical Weather Central (FNWC) in Monterey, California. This experiment has no real-time data requirements,

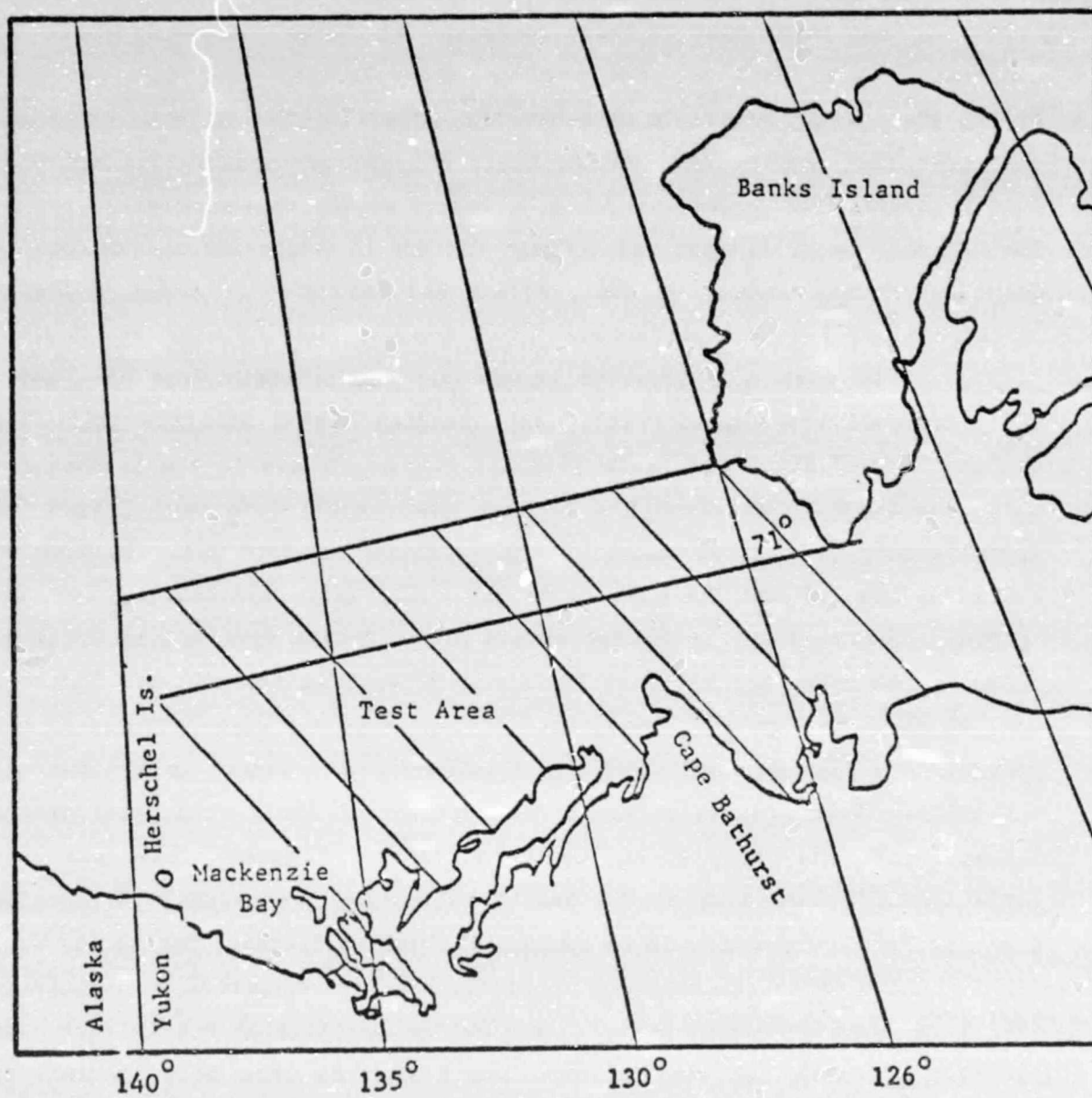


FIGURE 1. BEAUFORT SEA TEST AREA

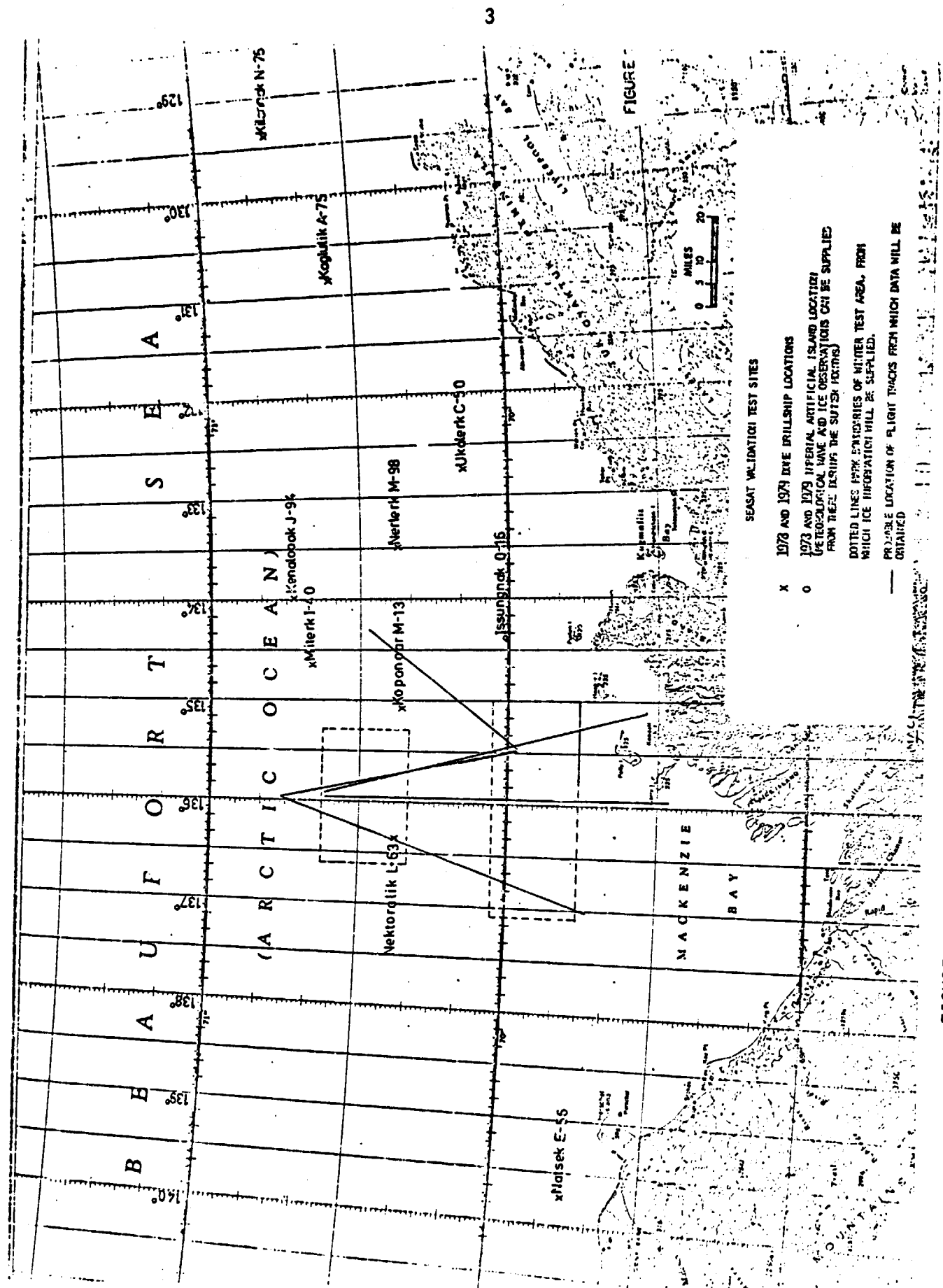


FIGURE 2. POSSIBLE LOCATIONS OF SEASAT VALIDATION TEST SITES

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but the participants are interested in the real-time distribution system which will be evaluated through Experiment No. 22 in cooperation with these Canadian companies.

#### Summary of the Physical Environment

- (1) The ice regime includes three zones:
  - (a) Landfast ice which extends out to the 60-foot water depth
  - (b) The shear zone which extends out to between 60 and 100 miles from shore
  - (c) The polar pack.
- (2) Breakup of the fast ice occurs every summer, producing ice-free conditions in coastal waters. The extent of this ice-free zone in coastal waters varies significantly from year to year. In good years, the edge of the polar pack may recede 300 miles while in bad ice years a clearance of 20 miles is the maximum.
- (3) The differences in fetch from year to year affect significant wave heights during the summer months.
- (4) The area seems to be sheltered from the effects of the Beaufort Gyral. Dynamics of ice movement are complex and are probably influenced by local winds and currents.
- (5) The discharge of fresh water from the Mackenzie River is an important factor affecting ice growth. Ice growth commences first in coastal waters and progresses seaward by steps. The rate of progression and number of steps depend on yearly meteorological conditions.

### Experiment Motivation

Ice reconnaissance in the past has been devoted primarily to the yearly resupply program to Arctic communities. The growing industry presence in the Beaufort Sea imposes increased and new demands on ice reconnaissance. Apart from the increase in shipping for summer supply operations, exploration and production activities are conducted on a year-round basis.

Under consideration for the Arctic region is the extension of the shipping season with suitable ice-strengthened vessels for the removal of oil and minerals, the increased use of drillships and the building of offshore structures. Exploration from artificial islands is already under way in the Mackenzie Delta region of the Beaufort Sea. In the Arctic Islands, wells have been drilled from rigs situated on artificially thickened floes. Drillships have operated in the southern Beaufort Sea since the summer of 1976. Presently, artificial island building costs are around \$245,000 per day. It is estimated that wells drilled by the drillships in the deeper water will cost around \$40 million.

The shortness of the summer open-water season in the Arctic makes the most efficient optimization of equipment essential. In drillship operation and for the deployment of equipment for island building, accurate prediction of pack ice movement is essential if unnecessary moves from location are to be avoided. Apart from the cost involved, unnecessary moves in drillship operation could delay the completion of a well until the following year.

### Objectives/Purpose

The purpose of this study is to evaluate active and passive microwave data obtained from Seasat and from the SURSAT Project as an aid to improving oil and gas exploration operations in the ice-infested waters of the southern Beaufort Sea. Primary specific Seasat objectives are to:

- (1) Evaluate active and passive microwave imagery for detection of total ice cover and ice boundaries on a year-round basis.

- (2) Identify ice types, distribution, and features such as pressure ridges and any changes in distribution with time.
- (3) Evaluate the applicability of Seasat data for determining wind speed and direction, wave height and directional period and sea surface temperature.
- (4) Assess the utility and benefits of Seasat and related satellite data to offshore petroleum operations in light of the ice interference aspect.

A secondary objective is to determine the feasibility of the altimeter data for indicating the degree of ice roughness and ice edge position location.

#### Approach

The Seasat satellite failed on 10 October 1978, having yielded 3 months of data which will be provided to the three Canadian companies in non-real time in the form of Geophysical Data Records (GDRs) and Synthetic Aperture Radar (SAR) data. The GDRs (primarily waves and winds) and SAR imagery will be used in a Seasat data evaluation case study to validate sensor capability and evaluate the forecasting value of the sensor data. Three periods between July and September 1978 have been selected for analysis to coincide with ice movements and with the collection of surface truth data. The industry participants will conduct special workshops on data analysis and evaluation with other participants from Experiment Nos. 2 and 22. Based on the results of comparison and analysis, assessment will be made of the utility of Seasat-type data and their benefits to offshore oil and gas exploration in arctic operations and environment.

The qualitative aspects of the experiment such as comparison of satellite and aircraft data with surface truth information will be conducted by industry in the following manner. To meet Objectives (1) and (2), information from existing sources such as ice charts, satellite imagery and visual observations will be used for comparative purposes.

Aerial photography, aircraft SAR and SLAR imagery, visual and other data will be used for identification of ice composition and distribution.

Wind speed and direction data collected offshore by the participants will be correlated with the Seasat scatterometer and SMMR data. Surface-truth sea surface temperature will be used to determine the correlation and accuracy of SMMR brightness temperature to represent actual surface temperature. Also, determinations will be made as to whether SMMR temperature can be useful in freezeup prediction models.

Industry Data Requirements. Real-time data requirements are to be satisfied through Experiment No. 22 conducted by Atmospheric Environmental Services. Non-real-time data will be required to carry out the objectives of this experiment. NASA will provide the participating industries with the following data:

- (1) Seasat Geophysical Data Records (GDRs), including altimeter ( $H_{1/3}$ ), scanning multifrequency microwave radiometer (SMMR) wind magnitude, Seasat-A scatterometer system (SASS) wind magnitude and direction, and SMMR sea surface temperature.
- (2) Synthetic aperture radar (SAR) imagery: three to ten passes.

The SURSAT Project Office will provide the following data products:

- (1) Pseudocolor images of observed brightness temperature from the Nimbus project
- (2) Processed data from the Convair 580 flight passes.

The minimum accuracy required by the industry participants for the altimeter data is  $\pm 1$  m. For the SASS data, the minimum accuracy required is  $\pm 3$  to 5 m/sec for wind magnitude and  $\pm 20^\circ$  for wind direction. All wave, wind speed and direction readings are requested for the following periods:

- 27 July - 3 August 1978
- 17 August - 24 August 1978
- 14 September - 21 September 1978.



Quality image products are needed of the first three of ten synthetic aperture radar (SAR) passes, with desired SAR ground swath and points of 74°N latitude on and 69°N latitude off:\*

- Pass ID #123, rev 605, on 8/8/78
- Pass ID #136, rev 648, on 8/11/78
- Pass ID #148, rev 691, on 8/14/78.

The seven additional SAR passes required include:

- Pass ID #45, rev 350, on 7/21/78
- Pass ID #184, rev 806, on 8/22/78
- Pass ID #198, rev 849, on 8/25/78
- Pass ID #412, rev 1382, on 10/1/78
- Pass ID #427, rev 1408, on 10/3/78
- Pass ID #450, rev 1451, on 10/6/78
- Pass ID #474, rev 1494, on 10/9/78.

The tracks of these SAR passes are depicted in Figure 3.

Surface Truth Data. The operating companies have collected environmental data at their artificial islands, from drillships and from their dredging barges, as detailed in Table 1. The parameters measured/observed include wave height, sea surface temperature, wind speed and direction, ice conditions, barometric pressure, cloud cover and visibility, as well as air temperature.

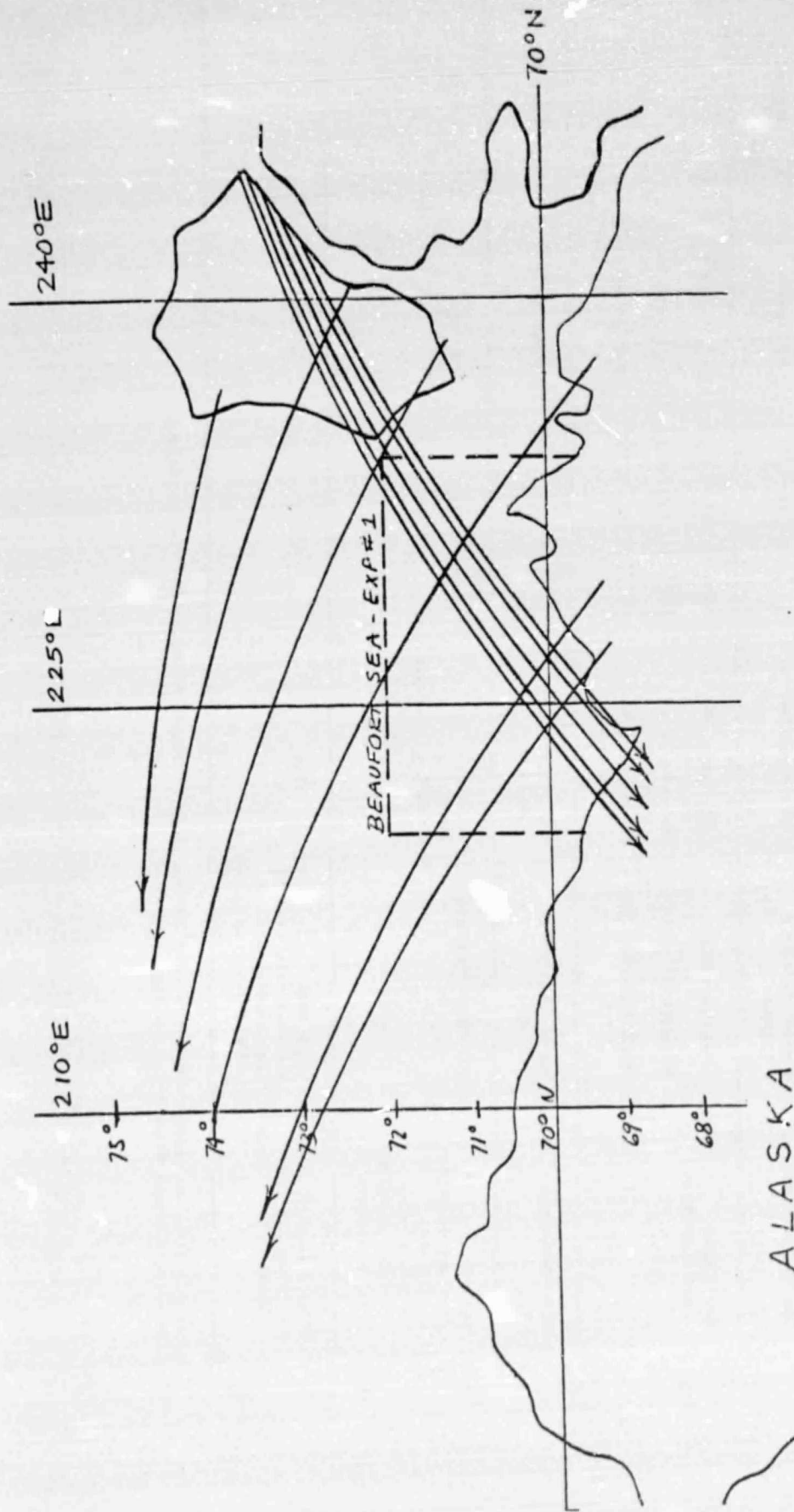
#### Data Format and Communication Equipment

The format of the Seasat data products should be as follows:

- (1) Tabular GDRs and 9-track computer-compatible tape (CCT)
- (2) Three film positives of SAR imagery and CCTs of 10 percent of the imagery

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\*The first three passes listed are on the NASA highest priority list for processing; the remaining seven passes have been requested by the experimenter, and NASA will consider processing them on a non-priority basis.



- NOTES:
- TRACK AS SHOWN IS CENTER OF SAR 100 KM GROUND SWATH. (NOT SATELLITE GROUND TRACK)
  - TRACKS WERE PLOTTED USING NODE CROSSINGS GIVEN IN 10/27/78 SAR CATALOG (W.E. BROVNI-JPL). PRE-LAUNCH PLOTTING DEVICE USED SO ACTUAL TRACKS MAY DIFFER BY UP TO  $\pm 0.5^\circ$  LONG.

FIGURE 3. SEASAT SAR PASSES OF INTEREST TO THE BEAUFORT SEA INDUSTRIAL EXPERIMENT

TABLE 1. SURFACE TRUTH DATA SUMMARY FOR SEASAT COMMERCIAL DEMONSTRATION EXPERIMENT NO. 1 (BEAUFORT SEA)

Parameter/Observation	Obs. Platform (Vessel, A/C, Platform, Buoy)	Instrumentation (Barom, Anemom, Thermom, Visual Obs.)	Location	Observation Dates (1978)	Frequency of Observation
Wave Height	Visual observations from dredging vessel	Visual Estimates	70°01'N, 134°19'1"W	July 29-Oct 5	3 hourly
Sea Surface Temp.	Beaver Mackenzie Dredge	1°C thermometer	-ditto-	-ditto-	-ditto-
Wind Speed and Direction	Dredging vessel Barge Camp No. 17 Barge Camp No. 208	Anemometer, 40 ft above SL Anemometer, 35 ft above SL Anemometer, 50 ft above SL	70°01'N, 134°19'1"W 69°37'N, 134°18'W 69°40'N, 132°50'W	July 29-Oct 5 Aug 1-Sept 15 July 15-Sept 28	-
Ice Conditions	Beaver Mackenzie Dredge	Visual obs and photos	70°01'N, 134°19'1"W	July 26-Oct 5	3 hourly*
Others Barom. pressure Altimeter Cloud cover and visibility Air temperature	All three locations	Barometer Altimeter Estimates of cloud Temperature in °C	Same locations	-ditto-	3 hourly
NOAA & Landsat Imagery Canadian & Fleet Weather Ice Charts	Daily NOAA All available Landsat All Canadian & Fleet Ice Charts	TBD	-ditto-	Summer	-

\*Ice was observed around the vessel only between July 26-August 5 and at the end of August.  
No ice was observed at the other two locations.

- (3) Three film positives and one negative (for Esso Resources Canada Ltd.) of Nimbus imagery

- (4) Tabular data and imagery for Convair aircraft data.

Data should be shipped by mail to the companies involved (Calgary, Alberta, Canada).

#### Reporting and Schedule

Guidelines for reporting the experiment results are discussed in the paragraphs below.

Progress Reports. As coordinator of this experiment, Battelle will submit periodic progress/status reports to NASA HQ. It is expected that the experimenter will provide inputs for these progress reports, but this is not a formal requirement. Battelle will provide the experimenter with copies of all such reports submitted to NASA.

Final Report. A final report (one camera-ready copy and four bound copies) will be prepared by the experimenter upon completion of the experiment, but not later than December 31, 1980. It is suggested that this report be prepared for general dissemination in accordance with good reporting practice. It may include experiment objectives, experiment description, techniques and procedures employed for the data analysis and assessment, conclusions, and recommendations. Also desirable is the experimenter's assessment of the results in terms of:

- (1) Potential contribution of the Seasat-type data to the experimenter's future needs
- (2) Characteristics of an operational satellite information system that is of importance to the users.

Also, an interim final report will be prepared and submitted to the SURSAT Office with a copy to NASA by October 31, 1979.

Schedule. A planning schedule for this experiment in the Beaufort Sea is shown in Figure 4.





**LABRADOR SEA OIL, GAS AND SEA ICE  
(ASVT EXPERIMENT 2)**

**NASA/TOTAL EASTCAN EXPLORATION LTD.  
AND ESSO RESOURCES CANADA LTD.**

**COOPERATIVE EXPERIMENT PLAN**

**July 1978**

**AMENDMENT 1**

**MARCH 1979**

**NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
Office of Space and Terrestrial Applications  
Washington, D. C. 20546**

## EXPERIMENT SUMMARY

ASVT EXPERIMENT: No. 2

TITLE: Labrador Sea Oil, Gas and Sea Ice

EXPERIMENT REPRESENTATIVE/ORGANIZATION: (M. Jozan/D. Berenger) Total Eastcan Exploration Ltd., Bow Valley Square, 1600, 202-6th Avenue, S.W., Calgary, Alberta T2P 2W6, Canada. Telephone: (403) 264-9770 and (G. Spedding) Esso Resources Canada Limited, 339-50th Avenue, S. E., Calgary, Alberta T2G 2B3, Canada. Telephone: (403) 259-0335.

COORDINATOR: For U.S. (A. George Mourad) Battelle's Columbus Laboratories, 505 King Avenue, Columbus, OH 43201. Telephone: (614) 424-0097; and (Dick Gedney) NASA/LeRC, 21000 Brookpark Rd., Cleveland, OH 44135. Telephone: (216) 433-4000, Ext. 209.

For Canada (René Ramseier) Surveillance Satellite Project Office (SURSAT), Department of Energy, Mines, and Resources, 580 Booth St., Ottawa, Ontario K1A 0Y7, Canada. Telephone: (613) 995-9261.

EXPERIMENT LOCATION: Test area is bounded by coordinates 45°-65°N and from shore out to 50°W longitude.

OBJECTIVE/PURPOSE: To verify Seasat data with industry-collected surface truth data for oceanographic, meteorologic and sea ice monitoring and to assess the utility and benefits of Seasat data to offshore drilling, design and production operations.

APPROACH: Surface truth data on wind, wave, temperature, pressure and ice cover, within the existing or planned framework of operations and research programs will be collected by the participants. These data will be processed, analyzed and used for comparison with and validation of Seasat data and sensors. Based on the results of comparison, assessment will be made of the Seasat data utility and benefits to offshore facilities design and production operations.

DATA REQUIREMENTS: Non-real-time data to include (1) Seasat GDR observations, (2) SAR data: three passes, (3) any available SAR imagery from Convair 580 and (4) Nimbus SMMR imagery. Items (3) and (4) will be provided by SURSAT.

DATA FORMAT AND FREQUENCY: Non-real-time data on 9-track tapes and printout. Imagery from SAR on film positives and CCT's of 10 percent of the imagery whenever available.

COMMUNICATIONS EQUIPMENT AND DATA DELIVERY: GDR data tapes and/or printouts to be mailed to the participating companies in Calgary.

SURFACE TRUTH DATA: Data include ice cover data, sea state and meteorological data from drillships and buoys, and aircraft flights.

### Labrador, Sea Oil, Gas and Sea Ice Experiment

This experiment is being conducted by two Canadian oil and gas companies in cooperation with NASA for the purpose of evaluating the potential that Seasat and related satellite data have for affecting the decision processes that must routinely be made during offshore oil and gas exploration, design, drilling, and production operations in ice and iceberg infested areas of the Labrador Sea. The ultimate benefits expected through the use of these data include enhancement of human safety and reduction of costs or losses in current and future operations.

Petroleum and natural gas exploration permits have been issued covering most of the offshore waters of the Canadian East Coast, and exploratory drilling has already been carried out off the Labrador coast. The Labrador Sea test area is of interest to two Canadian companies: Total Eastcan Exploration Ltd. and Esso Resources Canada Ltd. The Canadian Surveillance Satellite (SURSAT) Project Office is the liaison for this experiment with the two Canadian companies. The test area is shown in Figure 1. Its boundaries are 45 to 65 degrees north latitude and up to 500 km (300 miles) offshore.

The experiment participants currently have environmental data taken from buoys, aircraft and drillships operating in the Labrador Sea test area that will be used to determine the applicability and benefit of Seasat-type data for offshore oil and gas exploration in arctic operations and environment. Since the Seasat satellite failed on 10 October 1978, any further satellite data needed will be obtained from Nimbus, and the data products will be distributed by the Navy's Fleet Numerical Weather Central (FNWC) in Monterey, California. This experiment has no real-time data requirements, but the participants are interested in the real-time data distribution system which will be evaluated through Experiment No. 22 in cooperation with these Canadian companies.



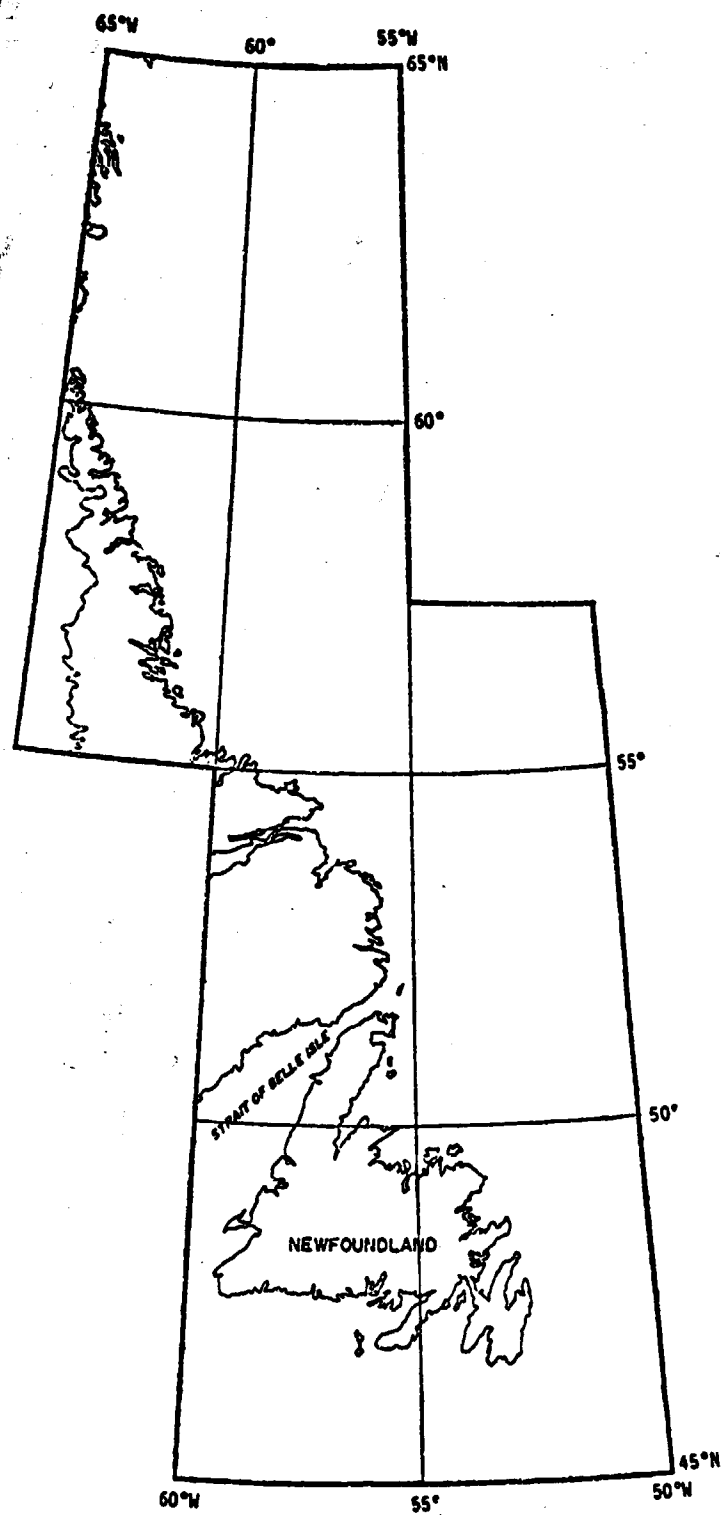


FIGURE 1. LABRADOR SEA TEST AREA

### Summary of the Physical Environment

The ice pack is constantly moving under current and wind action, and mainly consists of small to medium sized first-year ice floes with icebergs and multiyear ice floes trapped in it. Because of their large mass and high ultimate strength, multiyear floes and icebergs represent a real problem for structure design and operations. The design of an all-year production system requires knowledge of iceberg and multiyear flow distribution with time. However, multiyear floes are difficult to detect offshore (Labrador Sea) because of their small horizontal sizes (100 to 300 ft in diameter) and their low population.

The following is a description of some of the test area physical characteristics:

- Sea Ice      - Freezeup in about December  
                  Breakup in about July  
                  Pack ice continuously moving  
                  Mainly first-year ice  
                  Presence of multiyear ice (pressure ridges)
- Icebergs     - Presence of icebergs all year round  
                  Maximum frequency - February to August  
                  Minimum frequency - November and December  
                  Average size - about 1 million tons
- Sea State    - The sea conditions are generally good from  
                  breakup until September 15 and then they  
                  progressively deteriorate to become very  
                  bad in November and December
- Currents     - Main current is the Labrador current  
                  parallel to the coast going south.

At this time, the environmental data recorded in this area are limited, and probably will remain so for the next few years.

### Experiment Motivation

Exploratory drilling has already been carried out off the Labrador coast by Total Eastcan Exploration Ltd. and further drilling is planned. Esso Resources Canada Ltd. anticipates governmental approval for drilling in the Davis Strait area in 1979. Exploratory drilling will be

carried out in the summer open-water season. The shortness of the summer open-water season makes the most efficient optimization of equipment essential.

Operations will benefit from improved forecasting of the onset of ice breakup and ice formation, sea state conditions and detection of icebergs. In the future, if oil is discovered in this area, production of oil could possibly be undertaken on a year-round basis. This would involve navigation by ships in ice during the winter months. For this type of operation, all-weather and year-round coverage of ice conditions is required.

#### Objectives/Purpose

The objective is to evaluate Seasat data as an aid to improving exploration operations in the Labrador Sea area. Results of the experiment will be important to:

- (1) Improve the forecast of freezeup and breakup dates
- (2) Provide historical data for winds, waves, icebergs and ice cover
- (3) Provide near-real-time information for improving meteorological and wave forecasts
- (4) Provide ice cover and iceberg information on a near-real-time basis.

To date, only one tool has proven to be successful in detecting multiyear floes; that is airborne stereophotography, which is greatly limited by weather conditions and ground swaths. Some remote sensing systems (SAR, SLAR) have proven their ability to detect multiyear floes, but this was in the Beaufort Sea where the size and population are greater. Nevertheless, some of these instruments, specifically the SAR, may have potential for estimating multiyear floe population on the East Coast (Labrador Sea). It will be of great interest to test their capabilities in the East Coast pack ice using first an airborne support. If one of these instruments proves to be successful, Seasat and related satellites could be of great help in collecting data on multiyear floes.

### Approach

The Seasat satellite failed on 10 October 1978, having yielded 3 months of data which will be provided to the two Canadian companies in non-real time in the form of Geophysical Data Records (GDRs) and Synthetic Aperture Radar (SAR) data. The GDRs (primarily waves and winds) and SAR imagery will be used in a case study to verify Seasat data with industry-collected surface truth data for oceanographic, meteorologic and sea ice monitoring and to assess the utility and benefits of Seasat data to offshore exploration, drilling, design and production operations. Atmospheric Environmental Services (AES) of Canada (ASVT Experiment No. 22) will cooperate in providing forecasts using Seasat data for the Labrador Sea participants. The industry participants will conduct special workshops on data analysis and evaluation with other participants from Experiment Nos. 1 and 22. Based on the results of comparison and analysis, assessment will be made of the utility of Seasat-type data and their benefits to offshore oil and gas exploration in arctic operations and environment.

Surface truth data on wind, wave, temperature, pressure and ice cover (see the section on surface truth data for details) within the existing or planned framework of operations and research programs were collected by the companies involved. These data will be processed, analyzed and used for comparison with Seasat data that will be provided by NASA, and with Nimbus and Convair 580 data to be provided by the SURSAT office.

Real-time data from Seasat (obtained for Experiment No. 22) will be used as input in hindsight to the regional forecasts that will be provided by Atmospheric Environmental Services (AES) for the Labrador area (Experiment No. 22) to obtain localized forecasts. These localized forecasts will be evaluated against actual forecasts to determine the degree of Seasat improvement in forecasting. The Seasat GDRs will also be used for direct comparison with the surface truth data collected by instrumented rigs or platforms and assessed for their accuracy and contribution to building a historical data base that will be utilized to improve offshore facilities design and operations.

SAR and Nimbus imagery will be analyzed and compared with surface truth data taken by Convair 580 and other photographic flights and visual observations made by the industry. SAR imagery will then be evaluated for providing ice information as to type, distribution and properties. SAR data will also be evaluated against drill rig surface truth data and ice surveys for their application to detecting and determining iceberg size, position and tracks. Ultimately, and if SAR and SMMR types of imagery appear to be able to provide the useful data to satisfy the objectives of this experiment, the industry will be developing a real-time prediction capability on freezeup and breakup, ice cover and icebergs. The results of the analysis and evaluation will be documented in final reports and submitted to SURSAT and NASA, and will be made available for public dissemination.

Industry Data Requirements. Real-time data requirements will be satisfied through Experiment No. 22 conducted by Atmospheric Environmental Services. Non-real-time data will be required to carry out the objectives of this experiment. NASA will provide the participating industries with the following data:

- (1) Seasat Geophysical Data Records (GDRs), including altimeter ( $H_{1/3}$ ), scanning multifrequency radiometer (SMMR) wind magnitude, Seasat-A scatterometer system (SASS) wind magnitude and direction, and SMMR sea surface temperature.
- (2) Synthetic Aperture Radar (SAR) imagery: three passes.

The SURSAT Office will provide the above companies with the following data:

- (1) Pseudocolor images of observed brightness temperature from Nimbus-7
- (2) SAR and related data from Convair 580 aircraft flights.

The minimum accuracy required by the industry participants for the altimeter data is  $\pm 1$  m. For the SASS data, the minimum accuracy required is  $\pm 3$  to 5 m/sec for wind magnitude and  $\pm 20^\circ$  for wind direction. All wave, wind speed and direction data collected are requested for the following periods (in descending order of priority):

- 20 September - 10 October 1978
- 1 September - 19 September 1978
- 1 August - 31 August 1978
- 1 July - 31 July 1978.

Sea surface temperature data are also requested if an accuracy within 1°C absolute is achieved.

Quality image products are needed of three synthetic aperture radar (SAR) passes:

- Pass ID #180, rev 793, on 8/21/78, with desired SAR ground swath end points of 56.5°N latitude on and 60.5°N latitude off
- Pass ID #205, rev 879, on 8/27/78, with desired SAR ground swath end points of 54°N latitude on and 58°N latitude off
- Pass ID #418, rev 1395, on 10/2/78, with desired SAR ground swath end points of 61.5°N latitude on and 65.5°N latitude off.

Surface Truth Data. The operating companies have collected environmental data from their drillships, buoys, and oceanographic ships. The surface truth data available are presented in Tables 1 and 2, along with specifics as to observation platform, instrumentation, observation dates and frequency, and location.

#### Data Format and Communication Equipment

The format of the Seasat data products should be as follows:

- (1) Tabular GDRs and 9-track computer-compatible tape (CCT)
- (2) Two copies of SAR imagery on film positives for all passes and CCTs of 10 percent of imagery
- (3) Two film positives and one negative of Nimbus imagery
- (4) Tabular data and imagery for Convair aircraft data.

Data should be shipped by mail to the companies involved.

TABLE 1. TOTAL EASTCAN SURFACE TRUTH DATA SUMMARY FOR SEASAT  
COMMERCIAL DEMONSTRATION EXPERIMENT NO. 2

Parameter/Observation	Obs. Platform (Vessel, A/C, Platform, Buoy)	Instrumentation (Barom, Anemom, Thermom, Visual Obs.)	Location	Observation Dates (1978)	Frequency of Observation
Wave Height	Drillship	Waverider buoy about a mile from drill vessel	58°26'N 61°46'W 54°51'N 55°44'W	July 22-Sept 29 Oct 1-Oct 10	20 min recorded every 3 hr
Sea Surface Temperature	-ditto-	Thermometer, $\pm 0.1^{\circ}\text{C}$	-ditto-	-ditto-	One point value every 6 hr
Wind Speed & Direction	"	Anemometer, $\pm 3$ kts at 32.2 m above sea level	"	"	1 min average every 6 hr
Ice Conditions	"	Visual	"	"	Every hour
Barometric Pressure	-	$\pm 1$ mb at 18.2 m above sea level	"	"	One value per 6 hr
Air Temperature & Dew Point	-	$\pm 0.5^{\circ}\text{C}$ at 18.2 m above sea level	"	"	One value every 6 hr



TABLE 2. ESSO RESOURCES SURFACE TRUTH DATA SUMMARY FOR SEASAT  
COMMERCIAL DEMONSTRATION EXPERIMENT NO. 2

Parameter/Observation	Obs. Platform (Vessel, A/C, Platform, Buoy)	Instrumentation (Barom, Anemom, Thermom, Visual Obs.)	Location	Observation Dates (1978)	Frequency of Observation
Wave Height	10-m discuss buoy 2 ships' cruises	Waverider type accelerometer Visual obs.	61°40'N, 60°35'W (1) as far north as 66°30' (2) as far north as 68°	Oct 4-Oct 10 July 28-Aug 31 Aug 6-27	3 hourly; data transmitted to Suitland, Md. via GOES and H.F. back to Flatrock, St. John's then Edmonton
Sea Surface Temperature	10-m discuss buoy	Thermometer to 0.1°C	61°40'N, 60°35'W and from 2 ships' cruises	Oct 4-Oct 10 July 28-Aug 31 Aug 6-27	3 hourly; ships cruises infrequent, some taken during transects at biological cruises
Wind Speed & Direction	10-m discuss buoy, 2 ships' cruises (height not known)	Rendix Alrovane, Sears W.M.O. Standards	(1) as far north as 66°30' (2) as far north as 68°	July 28-Aug 31 Aug 6-Aug 27	3 hourly
Ice Conditions	No sea ice was encountered; an iceberg was sighted grounded off Brevort Island				

### Reporting and Schedule

Guidelines for reporting the experiment results are given in the paragraphs below.

Progress Reports. Battelle will submit periodic progress/status reports to NASA HQ. It is expected that the experimenter will provide inputs for these progress reports, but this is not a formal requirement. Battelle will provide the experimenter with copies of all such reports submitted to NASA.

Final Report. A final report (one camera-ready copy and four bound copies) will be prepared by the experimenter upon completion of the experiment, but not later than December 31, 1980. It is suggested that this report be prepared for general dissemination in accordance with good reporting practice. It may include experiment objectives, experiment description, techniques and procedures employed for the data analysis and assessment, conclusions and recommendations. Also desirable is the experimenter's assessment of the results in terms of:

- (1) Potential contribution of the Seasat-type data to the experimenter's future needs
- (2) Characteristics of an operational satellite system that are of importance to the users.

Also, an interim final report will be prepared and submitted to the SURSAT Office with a copy to NASA by October 31, 1979.

Schedule. A planning schedule for this experiment in the Labrador Sea is shown in Figure 2.

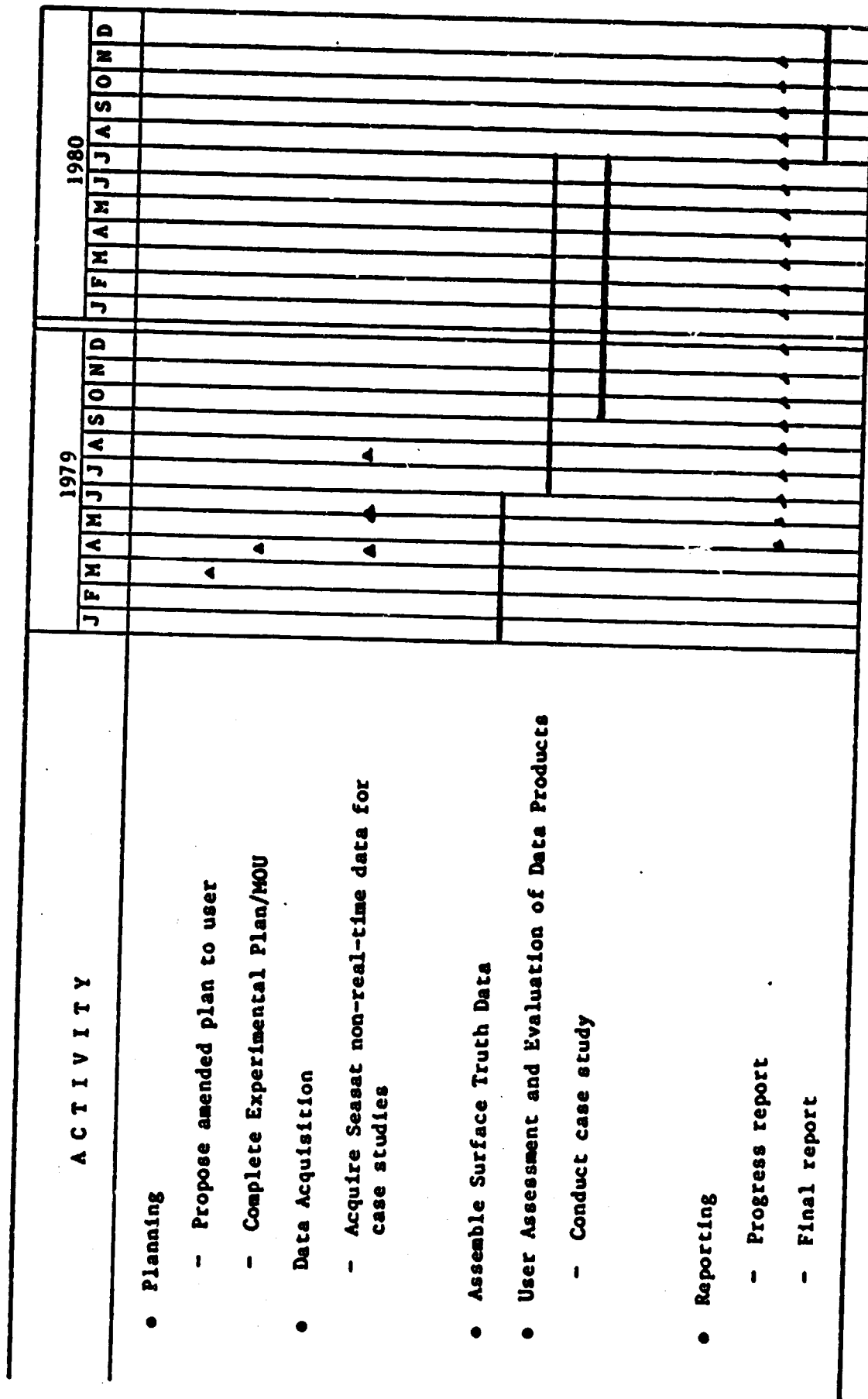


FIGURE 2. PLANNING SCHEDULE FOR THE LABRADOR SEA EXPERIMENT



**GULF OF MEXICO PIPELINES  
(ASVT EXPERIMENT 3)**

**NASA/AMERICAN GAS ASSOCIATION  
COOPERATIVE EXPERIMENT PLAN**

**June 1978**

**AMENDMENT 1**

**MARCH 1979**

**NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
Office of Space and Terrestrial Applications  
Washington, D. C. 20546**

## EXPERIMENT SUMMARY

ASVT EXPERIMENT: No. 3

TITLE: Gulf of Mexico Pipelines

EXPERIMENT REPRESENTATIVE/ORGANIZATION: (R. J. Simmons, Jr.) American Gas Association, c/o United Gas Pipe Line Company, 2 Allen Center, P.O. Box 1478, Houston, Texas 77001. Telephone: (713) 237-4531.

COORDINATOR: (A. George Mourad) Battelle's Columbus Laboratories, 505 King Avenue, Columbus, Ohio 43201. Telephone: (614) 424-5097.

EXPERIMENT LOCATION: The test area includes the entire Gulf of Mexico from the western Florida coast to the Mexican border.

OBJECTIVE/PURPOSE: To improve the design criteria for pipeline and correlate the effect of Seasat and related satellite data with subsurface and ocean bottom conditions, and to improve real-time prediction capability and the accuracy of predicting severe storms.

APPROACH: This experiment will be conducted in two parts. Part 1 involves the conduct of a case study to evaluate the utility of Seasat-type data. Documented times of significant weather episodes in the Gulf of Mexico during the Summer of 1978 are available. Seasat data will be used as input to generate forecasts on selected days. These forecasts will then be compared with the original forecasts generated at those times. In addition, Seasat data will be compared with available surface truth data, and determinations will be made as to how effectively they can be used independently and/or how these data can supplement existing measurements on the effects of waves and severe storms on pipeline design and operations. Part 2 involves the use and evaluation of the data distribution system using FNWC and Nimbus data.

DATA REQUIREMENTS: Real-time data to include some Nimbus and FNWC analysis and forecast products. Non-real-time data to include GDR records and three SAR passes.

DATA FORMAT AND FREQUENCY: Real-time data on tables and graphs/charts. Non-real-time data except SAR on magnetic tapes, and imagery for SAR.

COMMUNICATIONS EQUIPMENT AND DATA DELIVERY. A 1200-baud Vadic modem and Tektronix terminal will be provided by AGA or its contractor in Houston for the receipt of near-real-time data. NASA will pay for telephone line communications costs.

SURFACE TRUTH DATA. Surface truth data from a barge were collected during the life of Seasat. Other data have been requested by AGA from the operators of offshore platforms. In addition, documented forecasts and advisory services are available.

### Gulf of Mexico Pipelines Experiment

The Gulf of Mexico experiment is being conducted by the American Gas Association (AGA) in cooperation with NASA for the purpose of evaluating the potential that Seasat and related satellite data have for affecting the decision processes that must routinely be made during pipeline design and operations. The ultimate benefits expected through the use of these data include enhancement of human safety and reduction of costs or losses in current and future pipeline laying and operations.

The Gulf of Mexico is one of the major continental offshore U.S. areas for exploration, development and production of oil and gas. The American Gas Association is carrying out large-scale activities in the Gulf of Mexico, as shown in Figure 1. AGA member companies which will be actively involved in this experiment are: Michigan Wisconsin Pipe Line Company, Natural Gas Pipeline Company of America, Southern Natural Gas Company, Tennessee Gas Pipeline Company, Texas Eastern Transmission Corporation, Texas Gas Transmission Corporation, Transcontinental Gas Pipe Line Corporation, United Gas Pipe Line Company, Exxon Production Research Company, Florida Gas Transmission Company, Phillips Petroleum Company, Shell Development Company, Trunkline Gas Company, and Columbia Gulf Transmission Company. The primary test area will cover the offshore sector of the northern Gulf of Mexico between 18 and 30 degrees north latitude, and 80 and 90 degrees west longitude.

### Summary of the Physical Environment

The northern Gulf of Mexico is in a semitropic zone with ocean weather dominated by extratropical conditions during the winter and spring and tropical storms during the summer and fall. These storms, independently or interacting with each other, produce the primary weather conditions affecting the offshore and coastal areas of the northern Gulf. The two major classes of environmental systems which affect offshore oil and gas exploration, production and transportation can be broadly termed non-storm or storm conditions. Non-storm conditions primarily affect oil and gas operations, while storms most critically affect design criteria for

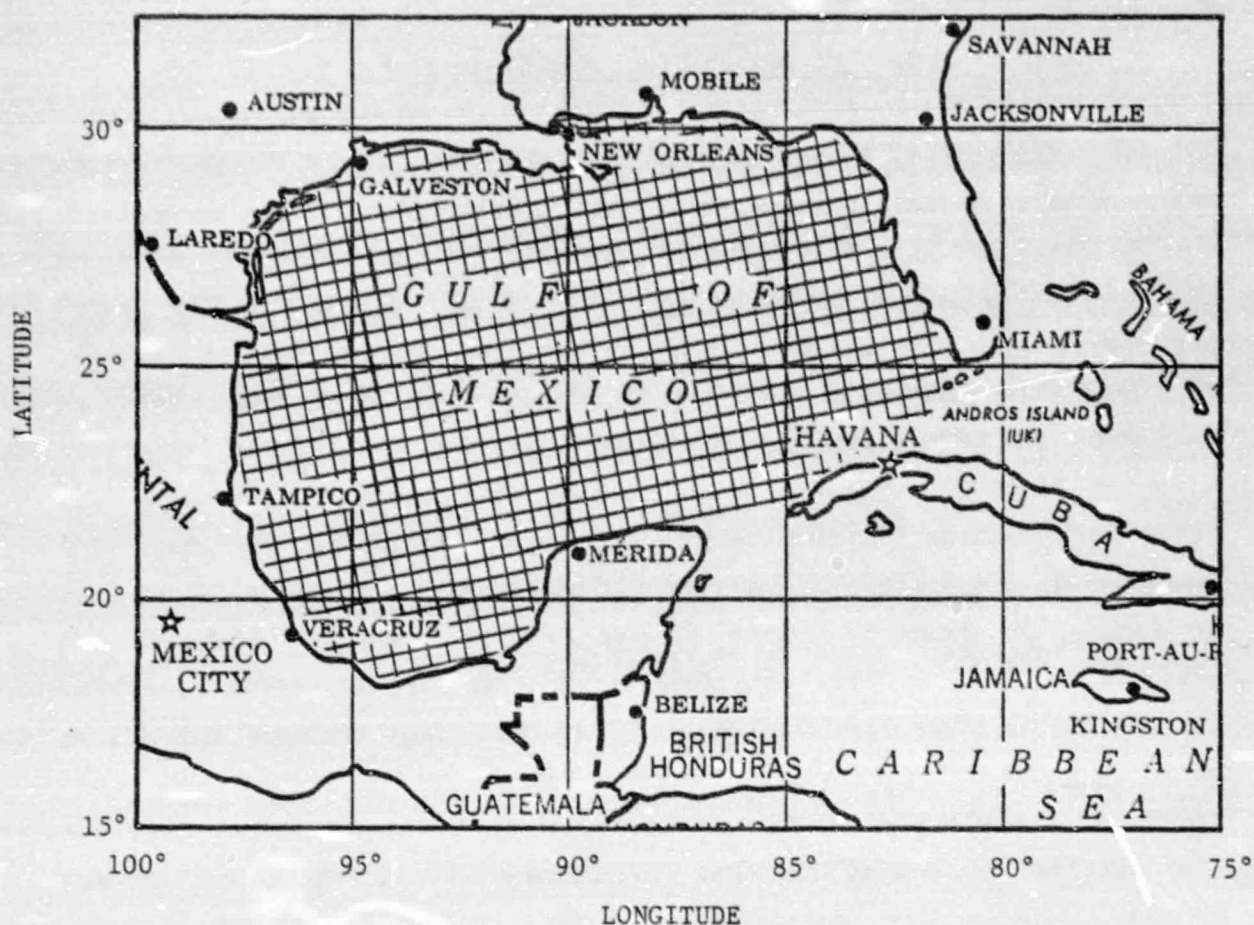


FIGURE 1. GULF OF MEXICO TEST AREA

offshore platforms, pipelines, and riser systems. Non-storm conditions include winds, waves, swell, tides, ocean currents, air and water temperatures, dew point, and barometric pressure. Storm conditions consist of extratropical storm or cold fronts and tropical storms such as hurricanes. Some specific effects encompass:

- Wind -- speed and direction are important for their effect on wind/wave generation for offshore areas. Forecasts of changes in wind speed and direction are critical to the wave forecast problem.
- Ocean swell -- immediately preceding the arrival of a frontal system, ocean swell frequently becomes quite large. Complex sea states can result when locally generated wind waves caused by squalls or frontal passage are superimposed.

- Currents -- complex seas in conjunction with ocean currents produce dynamic loadings for floating vessels, drilling barges, or pipe-laying barges.

AGA currently has environmental data taken in 1978 on a pipelaying barge and records of significant weather episodes that will be used to determine the applicability and benefit of non-real-time Seasat data in pipelaying design and offshore operations. With the failure of the Seasat satellite on 10 October 1978, any near-real-time data provided by NASA from then onward will be obtained from other satellites such as Nimbus, and the data products will be distributed by the Navy's Fleet Numerical Weather Central (FNWC) in Monterey, California. Consequently, the focus of future work will be on establishing the viability of the real-time data distribution system.

#### Experiment Motivation

The predictability of the intensity, path, and speed of movement of both extratropical and tropical storms is critically dependent upon adequate measurements of oceanographic and meteorological parameters of the north Gulf itself. Although there has been an improvement in forecast capability, a critical need still exists for better definition of actual environmental conditions which exist at a given time. The scarcity of offshore environmental data severely handicaps the prediction of expected environmental conditions even a few hours in advance, let alone for longer range forecasts which are so economically important to offshore operations.

The inability to provide accurate storm intensity and path predictions has frequently caused the early shutdown of offshore oil and gas systems. Shutdowns have resulted in severe curtailments of critically needed oil and gas supplies, reducing current revenue and causing increased storage needs. Although many of the parameters of concern under non-storm conditions are also of concern during full hurricane conditions, their influences are normally different.

Complicating the forecast problem is the fact that ocean currents have multiple components, including general circulation, wind-driven, wave-induced hydrographic, tidal, turbidity, and Coriolis effects on currents.



Accurate interpretation of ocean current structure can be greatly augmented by adequate data concerning each of these components either obtained by direct measurement or inferred from surface water temperature measurements.

Air and water temperature also have a profound influence on fog forecasting in the offshore environment. Since so many offshore operations in the northern Gulf of Mexico are up to 150 miles from the closest shore base, helicopter transportation is heavily utilized. When fog persists for several days at a time, disruption of offshore operations is substantial. Additionally, the safety of helicopter operations requires that if fog can be anticipated, helicopter flights will not be attempted.

#### Objectives/Purpose

The overall objective of this experiment is to evaluate Seasat capability as an aid in establishing improved design criteria for offshore facilities (pipelines, platforms and gathering systems) as well as assisting in more cost-effective oil and gas operations. Specific objectives are to:

- (1) Validate sensor data by direct comparison with available surface truth data in the Gulf of Mexico and assess their usefulness for pipeline design and operations.
- (2) Evaluate Seasat data input to meteorological forecasts by comparison with existing forecasts at that time.
- (3) Evaluate the utility of a real-time data distribution system for future offshore operations.

#### Approach

The Seasat satellite failed on 10 October 1978, having yielded over 3 months of data, which will be provided to AGA in non-real time in the form of Geophysical Data Records (GDRs) and synthetic aperture radar (SAR) data. The GDRs will be used in the AGA Seasat data evaluation case study to validate sensor capability and evaluate the forecasting value of the sensor data. Documented times of significant weather episodes in the Gulf of Mexico during the Summer of 1978 are available for this experiment.

During that time, Vega Weather Service, Inc., was under contract to provide AGA member companies with forecast and weather advisory services. Thus, Vega has available detailed records. The Seasat GDRs will be used to formulate forecasts on selected days where severe weather conditions existed in the Gulf of Mexico. These forecasts will then be compared with existing records for that time. In addition, various platform operators have been asked to provide any surface truth data they may have collected during the life of Seasat. These data, as well as those that have already been obtained during the operation of pipelaying barges, will be used to validate sensor accuracy and quality. Based on the results of comparison and forecast evaluations, assessment will be made as to the utility of the data and the potential benefits that could be obtained from a future operational satellite system.

Unfortunately, none of the available SAR passes cover hurricane activities in the Gulf of Mexico (the Summer of 1978 was a quiet one regarding hurricanes in this area). However, NASA will make available three SAR passes obtained during periods of high winds and waves. These passes will be compared with available surface truth data and will be utilized in conjunction with other Seasat data to assess their overall contribution, if any, for determining storm size, intensity and path for forecasting purposes.

Available real-time or near-real-time data include FNWC products and some Nimbus satellite data. These products and data will be utilized and compared with meteorological forecasts and will be evaluated for their applicability and potential benefits to various pipeline design and operations. It should be noted that, at this point in time, the main objective in this area will be for AGA to evaluate the real-time data distribution system (telephone lines, terminals, timeliness, etc.) rather than the accuracy of the real-time data per se.

Industry Data Requirements. NASA will provide AGA with the following data:

- (1) Seasat Geophysical Data Records (GDRs), including altimeter ( $H_{1/3}$ ), scanning multifrequency microwave radiometer (SMMR) wind magnitude, Seasat-A scatterometer system (SASS)

wind magnitude and direction, and SMMR sea surface temperature

- (2) Synthetic Aperture Radar (SAR) imagery: three passes.
- (3) PNWC products, which include:
  - (a) Analysis products of wind, sea surface temperature, pressure field at sea level, 500, 700, and 850 mb levels,  $H_{1/3}$ , primary wave period and direction, and spectral wave data
  - (b) Forecasts products of pressure fields at above levels and  $H_{1/3}$ , primary wave period and direction
  - (c) A preferred forecast period of 24 hr.

The minimum accuracy required by AGA for the altimeter data is  $\pm 1$  m or 20 percent of the measured value. For the SASS data, the minimum accuracy required is  $\pm 4$  m/sec (or 20 percent of the measured value) for wind magnitude and  $\pm 45^\circ$  for wind direction. AGA SMMR minimum accuracy requirements for sea surface temperature data are  $\pm 1^\circ\text{C}$  relative and  $\pm 4^\circ\text{C}$  absolute. In all cases, the time period of interest is from 1 July to 10 October 1978. However, the highest accuracy achievable from Seasat sensors should be provided to AGA in order to ultimately determine their validity for replacing or minimizing the collection of surface measurements.

AGA needs quality image products of SAR passes during periods of high winds and waves in the Gulf of Mexico. For initial input, they have selected the following passes with desired SAR ground swath end points of  $25^\circ\text{N}$  latitude on and  $31^\circ\text{N}$  latitude off:

- Pass ID #196, rev 838 on 8/24/78
- Pass ID #182, rev 795 on 8/21/78
- Pass ID #105, rev 551 on 8/4/78.

Surface Truth Data. AGA currently has available environmental data observed from semistationary work barges at several locations in the Gulf of Mexico (see Table 1). Data available from these barges include wave heights, wind speed and direction, water depth and descriptions of the state of the sea. A sample of the collected barge data is shown in Table 2. In addition, Vega Weather Service, Inc., has documented, for AGA, detailed records of significant weather episodes in the Gulf of Mexico

occurring during the period 1 July to 10 October 1978. Table 3 is a summary of these weather episodes, and presents detailed information on weather forecasts and advisory services.

TABLE 1. INDEX SHOWING THE LOCATIONS OF SEMISTATIONARY WORK BARGES

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Brazos Area - Offshore, Texas  
 South Marsh Island Area (S.M.I.) - Offshore, Louisiana  
 West Cameron (W.C.) - Offshore, Louisiana  
 Vermilion (V. or Verm.)  
 Galveston Area (Galv.) - Offshore, Texas  
 High Island (H.I.) - Offshore, Louisiana and Texas  
 East Cameron Area (E.C.) - Offshore, Louisiana  
 Eugene Island Area (E.I.) - Offshore, Louisiana  
 Ship Shoal (S.S.) - Offshore, Louisiana

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#### Data Format and Communication Equipment

The format of the Seasat data products should be as follows:

- (1) Tabular and graphic GDR data
- (2) Two copies of SAR imagery on film positives.

The FNWC products should be in tabular and graphics formats with isopleths, coordinates and land masses identified. Contour intervals will be standard available formats. Mercator is the preferred map projection for presentation of FNWC products.

Real-time data will be transmitted by FNWC to the user in Houston upon callup by the user, once per day between the hours of 8 and 5 Central Daylight Time. Non-real-time data specified above should be provided by mail on 9-track computer compatible tapes (CCT), and the imagery should be provided on film positives and CCTs of 10 percent of the imagery.

Two 1200-baud Vadic modem and Tektronix terminals or equivalent will be provided by AGA or its contractor for receipt of near-real-time data. NASA will pay for the cost of telephone data transmission lines and for shipment of non-real-time data to the user in Houston.

TABLE 2. EXAMPLE OF SURFACE TRUTH DATA SUMMARY FOR SEASAT  
COMMERCIAL DEMONSTRATION EXPERIMENT NO. 3

DATE	TIME	OBSERVATION PLATFORM	INSTRUMENTATION	LOCATION (BLOCK)	WINDSPEED AND DIRECTION (MPH)	DESCRIPTION OF SEA	WAVE HEIGHT (FEET)	WATER DEPTH (FEET)
7-1-78	12:00	CONSTRUCTION BARGE	ANEMOMETER, VISUAL OBSERVATION	A-102 BRAZOS 132 SMI 235 W.C. 331 VERM.	SE 10-15 SW 0-5 SW 8-10 S 5-10	MODERATE CALM CALM CALM	3-4 2-3 1-2 1-3	171 220 69 216
7-2-78	-DITTO-	-DITTO-	-DITTO-	A-102 BRAZOS 132 SMI 240 GALV. 331 VERM.	S 15-20 SW 5-10 SW 10-15 SE 5-10	MODERATE CALM MODERATE CALM	4-6 1-2 2-4 1-3	173 220 55 216
7-3-78	"	"	"	-DITTO-	S 15-20 SW 5-10 SW 10-15 SE 10-15	ROUGH CALM MODERATE CALM	5-7 2-3 2-4 1-3	175 220 65 216
7-4-78	"	"	"	A-101 BRAZOS 131 SMI 256 GALV. 106 SMI	SE 15-20 S 5-10 S 5-10 SW 5-10	MODERATE CALM CALM CALM	3-5 2-3 2-3 1-3	170 210 50 195

TABLE 3. SUMMARY OF SIGNIFICANT WEATHER EPISODES IN THE  
GULF OF MEXICO FROM 1 JULY-10 OCTOBER 1978

DATE	LOCATION	REMARKS
21-22 JULY	NW GULF	UPPER LEVEL DISTURBANCE GENERATED NUMEROUS THUNDERSTORMS WITH INCREASES IN WINDS AND WAVES
29-31 JULY	TX COAST SOUTH OF CORPUS CHRISTI	TROPICAL SHOWER ZONE SW GULF, DEVELOPED INTO TROPICAL STORM AMELIA
5-8 AUG	CENTRAL GULF TEXAS COAST	TROPICAL SHOWER ZONE IN THE CENTRAL GULF DEVELOPED INTO TROPICAL STORM BESS
26-28 AUG	-DITTO-	TROPICAL STORM DEBRA
12-13 SEPT	NW GULF	NUMEROUS TROPICAL THUNDERSTORMS WITH INCREASES IN WINDS AND SEAS
7 OCT	-DITTO-	STRONG NEW WINDS, ROUGH SEAS
5-6 SEPT	"	GOOD EXAMPLE OF A "QUIET" PERIOD

### Reporting and Schedule

Guidelines for reporting the experiment results are given in the paragraphs that follow.

Progress Reports. Battelle will submit periodic progress/status reports to NASA HQ. It is expected that the experimenter will provide inputs for these progress reports, but this is not a formal requirement. Battelle will provide the experimenter with copies of all such reports submitted to NASA HQ.

Final Report. A final report (one camera-ready copy and four bound copies) will be prepared by the experimenter upon completion of the experiment, but not later than December 31, 1980. It is suggested that this report be prepared for general dissemination in accordance with good reporting practice. It may include experiment objectives, experiment description, techniques and procedures employed for the data analysis and assessment, conclusions, and recommendations. Also desirable is the experimenter's assessment of the results in terms of:

- (1) Potential contribution of Seasat-type data to the experimenter's future needs
- (2) Characteristics of an operational satellite system that is of importance to the users.

Schedule. A planning schedule for this experiment in the Gulf of Mexico is shown in Figure 2.

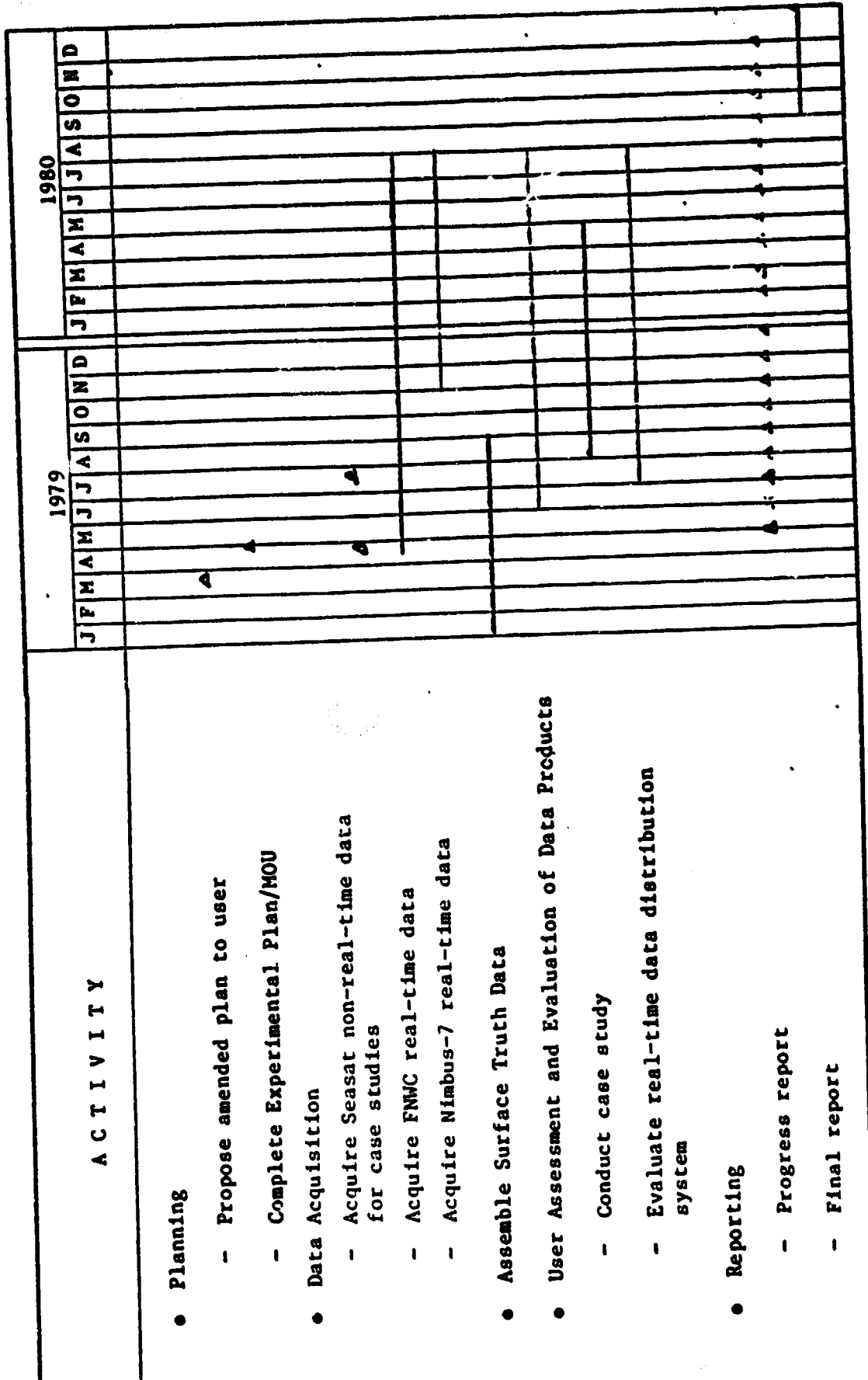


FIGURE 2. PLANNING SCHEDULE FOR GULF OF MEXICO PIPELINES EXPERIMENT





U.S. EAST COAST OFFSHORE OIL AND GAS  
(ASVT EXPERIMENT 4)

NASA/CONTINENTAL OIL COMPANY  
COOPERATIVE EXPERIMENT PLAN

June 1978

AMENDMENT 1

MARCH 1979

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
Office of Space and Terrestrial Applications  
Washington, D. C. 20546

## EXPERIMENT SUMMARY

ASVT EXPERIMENT: No. 4

TITLE: U.S. East Coast Offshore Oil and Gas

EXPERIMENT REPRESENTATIVE/ORGANIZATION: CONOCO (Frank Rose), P.O. Box 2197, Houston, TX 77001. Telephone: (713) 965-2614.

COORDINATOR: (A. George Mourad) Battelle's Columbus Laboratories, 505 King Avenue, Columbus, OH 43201. Telephone: (614) 424-5097.

EXPERIMENT LOCATION: The area of the North Atlantic between 25°-45°N and 50°W to the U.S. coast.

OBJECTIVE/PURPOSE: To compare Seasat and related satellite data with in situ measured data and to determine the applicability and benefit of Seasat and related data for establishing design and operational criteria for offshore facilities and for real-time input to oceanographic-meteorological forecasts.

APPROACH: The Seasat and related data to be provided by NASA will be compared by CONOCO with the surface truth data taken during the test period by instrumented drill rigs. Based on these comparisons, the data will be assessed in terms of applicability to development of long-term data bases for structural design and operations, as well as benefits derived from upgrading forecasts.

DATA REQUIREMENTS: Real-time data to include some Nimbus and FNWC products and forecasts. Non-real-time data to include (1) four SAR passes and (2) Seasat GDR observations within a 100-km radius of the drilling unit.

DATA FORMAT AND FREQUENCY: Real-time data in tables, charts and graphs whenever available. Non-real-time data, except SAR, on magnetic tapes and imagery for SAR, either transparencies or positives.

COMMUNICATIONS EQUIPMENT AND DATA DELIVERY: A 1200-baud modem and graphics display terminal will be provided by CONOCO or its contractor in Houston for the receipt of charts. NASA will pay for the telephone line communications cost.

RFACE TRUTH DATA: CONOCO, as operator for the East Coast Rig Instrumentation Program (ECRIP), will provide surface truth data, from an instrumented drilling vessel, on waves (height and period), wind speed and direction, air and sea surface temperature, and barometric pressure. Also, meteorological observations may be available, if needed, from drill rigs of other ECRIP participants.

### U.S. East Coast Offshore Oil and Gas Experiment

This experiment is being conducted by the Continental Oil Company (CONOCO) in cooperation with NASA for the purpose of evaluating the potential that Seasat and related satellite data have for affecting the decision processes that must routinely be made during offshore oil and gas exploration and production. The ultimate benefits expected through the use of these data include enhancement of human safety and reduction of costs or losses in current and future operations.

The U.S. East Coast can be considered a frontier area in terms of offshore oil and gas exploration and possible production. The area is of interest to CONOCO as operator for the East Coast Rig Instrumentation Program (ECRIP), a joint industry oceanographic/meteorological data collection effort. Three general areas offer potential for development: the Georges Bank, Baltimore Canyon and the Georgian Embayment (see Figure 1). The Baltimore Canyon currently is the primary area of interest, with exploration activities presently underway in that area. Oceanographic/meteorological data will be required for determination of operational and design criteria. The region of primary interest will be bounded by 37°30'N-40°N latitude and 70°-73°W longitude and will be the test area for direct comparison of Seasat and related data with the drilling unit data. However, for use of Seasat data as input for forecasting, a larger area bounded by 25°-45°N and 50°W to the U.S. coastline is required.

CONOCO has environmental data taken in 1978 off the U.S. East Coast to determine the applicability and benefit of Seasat data for establishing design and operational criteria for offshore facilities. With the failure of the Seasat satellite on 10 October 1978, any real-time data provided by NASA from then onward will be obtained from other satellites such as Nimbus and the data products will be distributed by the Navy's Fleet Numerical Weather Central (FNWC) in Monterey, California. Consequently, the focus of future work will be on establishing the viability of the real-time data distribution system.

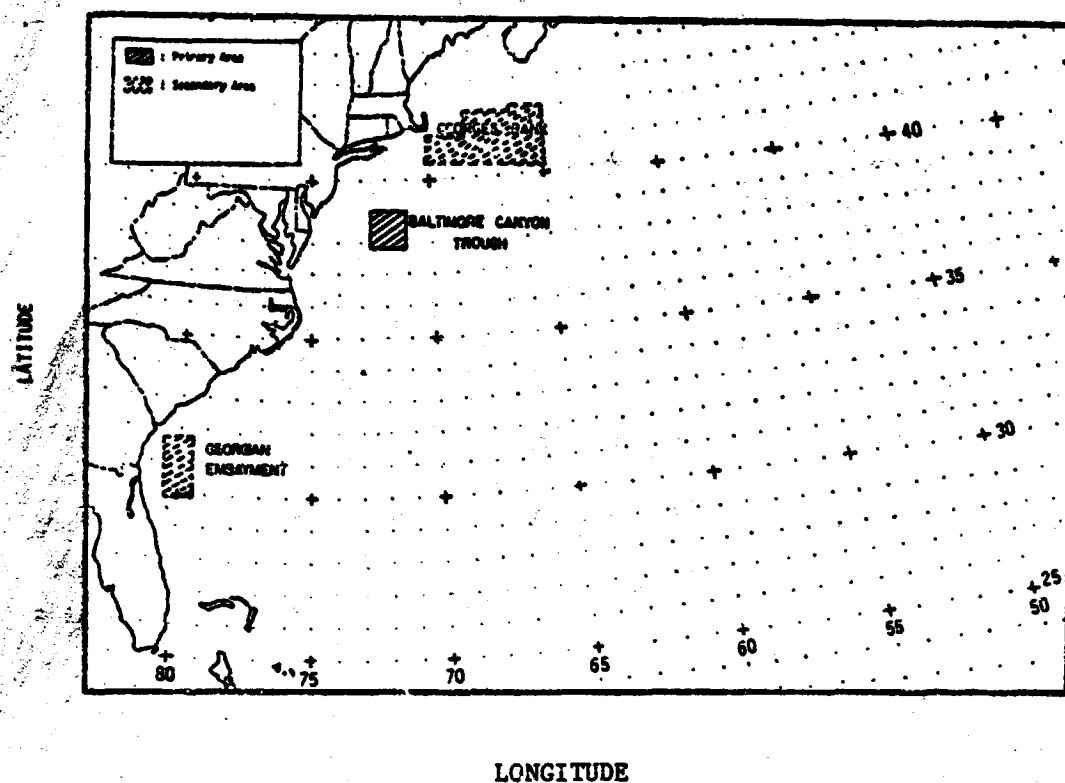


FIGURE 1. U.S. EAST COAST TEST AREA

#### Summary of the Physical Environment

The U.S. East Coast is characteristically a region of cyclogenesis (initial storm development). The general pattern of major tropical and subtropical storm growth and movement originally develops in the lower latitudes and eventually grows as it passes into the higher latitudes. More specifically, the test area can be affected by severe winter storms as well as hurricanes. Within the test area, westerly winds dominate during the winter and southwesterly winds dominate during the summer. Local waves produced by these winds closely follow the same directional distributions as those found for the winds. Tidal range will, in general, be less than 5 feet, with maximum associated tidal currents rarely exceeding 2 to 3 ft per sec. Water depths within the oil and gas development area of the Baltimore Canyon will vary from 100 to 600 feet.

### Experiment Motivation

The U.S. East Coast is an environmentally sensitive region for oil and gas development. If structural design and operational criteria are not to be unnecessarily conservative, then these criteria must be based on quality data obtained in a timely manner. Conventional data collection efforts normally concentrate on point measurement of data. Results of the measurements are often extrapolated to other regions by various modeling techniques. A basic instrumentation program to measure such parameters as wind, wave, current, tide and temperature with a real-time capability can easily cost hundreds of thousands of dollars per year per location. If the satellite sensor data are accurate, then they can be used to support data from in situ stations, if not eliminate the need for some of these stations.

Forecasting for marine operations along the East Coast will be a necessity. Severe winter storm activity and hurricanes could cause considerable downtime, and the ability to forecast these phenomena as accurately as possible will be desirable. Real-time measured data during these severe events play an important role in forecasting methodologies. However, it is usually during periods of severe weather that conventional instrumentation is most likely to fail. If the sensor data perform as specified and more reliable forecasts result within the test area, downtime due to waiting on weather could be reduced.

### Objectives/Purpose

The objectives of the experiment proposed for the U.S. East Coast test area are threefold:

- (1) Validation of sensor data--direct comparison between Seasat and surface truth data will be undertaken using data from instrumented drilling units and buoys.
- (2) Determination of the applicability and benefit of Seasat data for establishing design and operational criteria for offshore facilities.

- (3) Determination of the applicability and benefit of a Seasat-type real-time data distribution system in oceanographic-meteorological forecasts related to offshore operations.

#### Approach

The Seasat satellite failed on 10 October 1978, having yielded 3 months of data which will be provided to CONOCO in non-real time in the form of Geophysical Data Records (GDRs) and synthetic aperture radar (SAR) data. The GDRs will be used in CONOCO's Seasat data evaluation case study to validate sensor capability and evaluate the forecasting value of the sensor data.

CONOCO, program administrator of ECRIP, will collect environmental data suitable for forecasting and hindcast calibrations (see the section on surface truth data for details). All usable Seasat data within a 100-km radius of the instrumented drill rig or buoy will be obtained from NASA and will be used for direct comparison with the surface truth data. To make valid comparisons with the point values provided by the instrumented rig, it will be necessary to interpolate, extrapolate and interpret Seasat data, which represent average values and cover a large areal extent.

Seasat data along with simultaneous in situ measured values of surface truth parameters will be plotted to give visual comparisons. Regression analysis of these data pairs will be performed to obtain estimates of bias and standard deviation in the comparison. Additional statistical procedures, if warranted, because of the limited data base, will be undertaken for further analysis of the comparison. With due consideration to probable errors associated with in situ measurements, the data will then be assessed in terms of applicability to establishing design and operational

criteria as well as benefits derived from upgrading forecasts. CONOCO would prefer that NASA provide data to be used for direct comparison in magnetic tape form.

Unfortunately, none of the available SAR passes cover hurricane activities in the areas of interest, but NASA will make available four SAR passes obtained during periods of high winds and waves. The SAR passes obtained from NASA during high storm activities will be compared with the surface truth data to validate sensor capability. Assessment will then be made of the utility of the SAR images for measuring ocean parameters such as wave directional characteristics. In addition, examination of SAR data will be made for determining storm size, intensity and path for forecasting purposes.

Available real-time or near-real-time data include FNWC products and some Nimbus satellite data. The near-real-time satellite data and FNWC products may be utilized as real-time input to oceanographic and meteorological forecasts and will be evaluated for their applicability and potential benefits to various offshore oil and gas operations. It should be noted that, at this point in time, the main objective in this area will be for CONOCO to evaluate the real-time data distribution system (telephone lines, terminals, etc.) rather than the accuracy of the real-time data per se. The results of such analysis and evaluation, as well as recommendations concerning future operational systems, will be documented in a final report to be furnished to NASA.

Industry Data Requirements. NASA will provide CONOCO with the following data:

- (1) Seasat Geophysical Data Records (GDRs), including altimeter ( $H_1/3$ ), scanning multifrequency microwave radiometer (SMMR) wind magnitude, Seasat-A scatterometer system (SASS) wind magnitude and direction, and SMMR sea surface temperature.
- (2) Synthetic aperture radar (SAR) imagery: 4 passes.

(3) FNWC products, which include:

- (a) Analysis products of wind, air and sea surface temperature, pressure field at sea level,  $H_{1/3}$ , primary wave period and direction, and spectral data
- (b) Forecast products of pressure field at sea level, wind speed and direction,  $H_{1/3}$ , primary wave period and direction, and spectral data
- (c) Observation files of sea level pressure every 6 hr, and sea surface temperature (SST) every 12 hr
- (d) Two forecast periods (12 and 24 hr) are required, with priority for the 12-hr period.

(4) Nimbus data of wind and SST.

The minimum accuracy required by CONOCO for the altimeter data is  $\pm 1.5$  m or 30 percent of the measured value. For the SASS data, the minimum accuracy required is  $\pm 6$  m/sec (or 30 percent of the measured value) for wind magnitude and  $\pm 60^\circ$  for wind direction. CONOCO's SMMR minimum accuracy requirements for sea surface temperature data are  $\pm 1^\circ\text{C}$  relative and  $\pm 4^\circ\text{C}$  absolute. However, the highest accuracy achievable from Seasat sensors should be provided to CONOCO in order to ultimately determine their viability for replacing or minimizing the collection of surface measurements. In all cases, the time period of interest is from 1 July to 10 October 1978.

CONOCO needs quality image products of synthetic aperture radar (SAR) passes during periods of high winds in the Baltimore Canyon area ( $38-40^\circ\text{N}$  latitude and  $286-288^\circ\text{E}$  longitude). For initial input, they have selected the following passes (listed in order of priority), with desired SAR ground swath end points of  $37^\circ\text{N}$  latitude on and  $41^\circ\text{N}$  latitude off:\*

- Pass ID #379, rev 1318, on 9/27/78
- Pass ID #402, rev 1361, on 9/30/78
- Pass ID #327, rev 1232, on 9/21/78
- Pass ID #353, rev 1275, on 9/24/78.

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\*The first three passes are on the NASA highest priority list for processing; the fourth pass has been requested by the experimenter, and NASA will consider processing it on a non-priority basis.



Surface Truth Data. An industry program is under way for instrumenting U.S. East Coast drilling vessels. The purpose of this effort is to supply offshore environmental data for forecasting and hindcast calibrations within the East Coast area. Real-time measured data are being obtained by limited on-board processing, while more detailed analysis of the data is being performed on shore. Parameters to be measured are included in Table 1. CONOCO, as administrator of this project, has recommended and the Program Advisory Committee has agreed to release data collected from this program for verification of Seasat data. Observed meteorological data from other rigs may also be collected and compared. Data listed in Table 1, with the exception of sea surface temperatures, will be transmitted via the GOES satellite to NOAA in Suitland, Maryland. Particulars as to instrumentation, observation dates and frequency are presented in Table 2.

Observed or measured environmental data from drilling vessels are currently available at a number of sites in the Baltimore Canyon for the period July to October 1978. Data available from these locations include wave height, period and direction; sea surface temperature; wind speed and direction; surface current speed and direction; and barometric pressure, dew point and dry bulb air.

An itemized accounting of the various instrumented rig parameters is contained in Table 3, which not only provides a description as to how these parameters are obtained on board ship, but also gives further details as to the frequency of observation, estimated accuracy and other pertinent information.

TABLE 1. SURFACE TRUTH DATA TO BE PROVIDED BY INDUSTRY

Parameter	Sampling Interval	Data Product
Water surface profile	Continuous - 1 sec interval	Significant wave height Maximum wave height Significant period Maximum period Wave height spectra
Wind speed and direction	Continuous - 3 sec interval	Average 3-hr wind speed and direction Average 1-hr wind speed and direction Average 1-min wind speed and direction Average 3-sec wind speed and direction
Air temperature	1 sample/20 min	Air temperature time history
Sea surface temperature	1 sample/20 min	Sea surface temperature time history
Barometric pressure	1 sample/20 min	Pressure time history

Data Format and Communication Equipment

The format of the Seasat data products should be as follows:

- (1) Tabular and graphic GDR data on 9-track tapes readable on an IBM 370/158 system.
- (2) Two copies of SAR imagery on film transparencies or positives for all passes and computer-compatible tape (CCT) readable on an IBM 370/158 system of 10 percent of the imagery.

TABLE 2. SURFACE TRUTH DATA SUMMARY FOR SEASAT COMMERCIAL DEMONSTRATION  
EXPERIMENT NO. 4 (OFFSHORE U.S. EAST COAST)

Parameter/Observation	Obs. Platform (Vessel, A/C, Plat- form, Buoy)	Instrumentation (Barom, Anemom, Thermom, Visual Obs.)	Location	Observation Dates (1978)	Frequency of Observation
Wave Height, Period and Direction	Drillship	Waverider buoy, accuracy: $\pm 1\%$ of reading of height, $\pm 0.1$ -sec period	39°24'56"N, 73°06'04"W	Aug 30-Oct 10	Continuous, 1-sec intervals
Sea Surface Temperature	Drillship	Thermistor AMS: $\pm 0.2^\circ\text{F}$	39°24'56"N, 73°06'04"W	Aug 30-Oct 10	1 sample/20 min preceding 6-hr reporting interval
Wind Speed & Direction	Drillship	Bendix 120 anemometer: $\pm 0.4$ kt for 0-9 kt winds, $\pm 0.9$ kt for 9-120 kt winds, $\pm 2^\circ$ in direction	39°24'56"N, 73°06'04"W	Aug 30-Oct 10	Continuous, 3-sec average measured at 20-min periods
Surface Current (Speed & Direction) Barometric Pressure, Dew Point and Dry Bulb Air	Drillship	AMS: $\pm 0.05$ kt for $< 1$ kt $\pm 0.1$ kt for $< 1$ kt $\pm 2.8^\circ$ in direction	39°24'56"N, 73°06'04"W	Aug 30-Oct 10	Internal recording vector average speed over 15-min period

Note: Wind speed is adjusted to standard 10-m anemometer height through use of a wind profile power law. Wave height and period utilize the 1024 sample points (one point/sec) immediately preceding the 6-hr reporting interval, in feet. The period corresponds to the highest one-third zero up-crossing waves. Wave direction is observed visually.

The FNWC product format should be in graphics with isopleths and coordinates identified. Contour intervals will be standard available formats. Mercator is the preferred map projection for presentation of FNWC products.

Real-time data will be transmitted by FNWC to CONOCO or its contractor in Houston upon callup by the user, at 6-hr intervals starting at 0 hr Central Time.

Non-real-time data for GDRs (specified above) should be collected on 9-track tapes or in tabular form within a 100-km radius of the instrumented rig or buoys and sent to CONOCO by mail. SAR imagery films are to be mailed after they have been processed.

A 1200-baud Vadic modem and Tektronix terminal or equivalent will be provided by CONOCO and/or its contractor in Houston for the receipt of the near-real-time data. NASA will pay for the cost of telephone data transmission lines and for shipment of non-real-time data to the user.

#### Reporting and Schedule

Guidelines for reporting the experiment results are given in the paragraphs below.

Progress Reports. Battelle will submit periodic progress/status reports to NASA HQ. It is expected that the experimenter will provide inputs for these progress reports, but this is not a formal requirement. Battelle will provide the experimenter with copies of all such reports submitted to NASA.

Final Report. A final report (one camera-ready copy and four bound copies) will be prepared by the experimenter upon completion of the experiment, but not later than December 31, 1980. It is suggested that this report be prepared in accordance with good reporting practice. It may include experiment objectives, experiment description, techniques and

TABLE 3. DEFINITION OF INSTRUMENTED RIG PARAMETERS

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 NTL 78-5 Item A-1-a

All wind speeds will be adjusted to standard 10-meter anemometer height through use of a wind profile power law which will produce reasonably accurate results and is an accepted technique used by many meteorologists. The power law to be used is of the form:

$$W_u = W_l \left( \frac{Z_u}{Z_l} \right)^e,$$

where

$W_u$  is the wind speed at the upper height,  $Z_u$ ,

$W_l$  is the wind speed at the lower height,  $Z_l$ ,

and

$e$  is the power law exponent.

A value of  $e = 0.14$  will be used for the wind speed adjustment.

All wind speeds will be reported in units of knots.

**Average Wind Speed:** The average wind speed, in knots, will be determined as the scalar average of the 3-second wind speeds measured during the 20-minute period immediately preceding the 6-hour reporting interval.

**Average Wind Direction:** The average wind direction, in degrees true, will be determined as the vector average of the 3-second wind vector velocities measured during the 20-minute period immediately preceding the 6-hour reporting interval.

**Maximum Wind Speed:** The maximum wind speed, in knots, will be determined as the maximum 1-minute scalar average of 3-second values obtained each minute during the 20-minute period immediately preceding the 6-hour reporting interval.

**Maximum Wind Direction:** The maximum wind direction, in degrees true, will be determined as the resultant direction of the 1-minute vector average of the 3-second wind velocities corresponding to the same 1-minute interval used to determine the maximum wind speed.

**Peak Gust Wind Speed:** The peak gust speed, in knots, will be determined as the maximum 3-second sample value measured during the 20-minute period immediately preceding the 6-hour reporting interval.

**Peak Gust Direction:** The peak gust direction, in degrees true, will be determined as the measured direction of the 3-second sample value corresponding to the 3-second peak gust wind speed.

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TABLE 3. (Continued)

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NTL 78-5 Item A-1-b

Barometric Pressure: The barometric pressure, in millibars, will be determined from the sample point measured immediately preceding the 6-hour reporting interval.

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## NTL 78-5 Item A-e

Dry-Bulb Air Temperature: The dry-bulb air temperature, in degrees Fahrenheit, will be determined from the sample point measured immediately preceding the 6-hour reporting interval.

Dew Point: The dew point, temperature, in degrees Fahrenheit, will be determined from the sample point measured immediately preceding the 6-hour reporting interval.

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## NTL 78-5 Item A-1-f

Wave Height: The computation of significant wave height, in feet, will utilize the 1024 sample points (one point per second) immediately preceding the 6-hour reporting interval and will be determined as the average height of the highest one-third zero up-crossing waves.

Wave Period: The computation of significant wave period will utilize the 1024 sample point immediately preceding the 6-hour reporting interval and will correspond to the average period of the highest one-third waves which were used to determine the significant wave height.

Wave Direction: Observed (by human sight) estimate of wave direction as determined immediately prior to the 6-hour reporting interval.

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## NTL 78-5 Item A-1-g

Surface Current Speed: Surface current speed, in knots, will be determined by the vector average speed over the 15-minute period immediately preceding the 6-hour reporting interval.

Surface Current Direction: Surface current direction, in degrees true, will be determined by the vector average direction over the 15-minute period immediately preceding the 6-hour reporting interval.

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## NTL 78-5 Item A-1-c

Surface Water Temperature: Surface water temperature, in degrees Fahrenheit, will be determined from the sample point measured immediately preceding the 6-hour reporting interval.

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procedures employed for the data analysis and assessment, conclusions and recommendations. Also desirable is the experimenter's assessment of the results in terms of:

- (1) Potential contribution of Seasat-type data to the experimenter's future needs
- (2) Characteristics of an operational satellite system that are of importance to the users.

Schedule. A planning schedule for this experiment off the U.S. East Coast is shown in Figure 2.

ACTIVITY	1979												1980											
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
• Planning																								
- Propose amended plan to user																								
- Complete Experimental Plan/MOU																								
• Data Acquisition																								
- Acquire Seasat non-real-time data for case studies																								
- Acquire FNWC real-time data																								
- Acquire Nimbus-7 real-time data																								
• Assemble Surface Truth Data																								
• User Assessment and Evaluation of Data Products																								
- Conduct case study																								
- Evaluate real-time data distribution system																								
• Reporting																								
- Progress report (Battelle)																								
- Final report																								

FIGURE 2. PLANNING SCHEDULE FOR THE U.S. EAST COAST OFFSHORE OIL AND GAS EXPERIMENT





WORLDWIDE OFFSHORE DRILLING AND  
PRODUCTION OPERATIONS

(ASVT EXPERIMENT 5)

NASA/GETTY OIL COMPANY

COOPERATIVE EXPERIMENT PLAN

June 1978

AMENDMENT 1

MARCH 1979

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
Office of Space and Terrestrial Applications  
Washington, D. C. 20546

## EXPERIMENT SUMMARY

ASVT EXPERIMENT: No. 5

TITLE: Worldwide Offshore Drilling and Production Operations

EXPERIMENT REPRESENTATIVE/ORGANIZATION: (H. DeMirjian/P. Wybro) Getty Oil Co.,  
3903 Stoney Brook Drive, Houston, TX 77063. Telephone: (713) 782-7172.

COORDINATOR: (A George Mourad) Battelle's Columbus Laboratories, 505 King  
Avenue, Columbus, OH 43201. Telephone: (614) 424-5097.

EXPERIMENT LOCATION: There are nine prospective areas of interest; two of these areas are currently available as experiment locations with suitable surface truth data, and it is anticipated that others will become available over the years. These areas are (1) Ibiza Marino (Spain), (2) Strait of Ontranto, (3) Offshore West Africa, (4) Northwest Australia, (5) U.S. East Coast, (6) Curacao, (7) Argentina, (8) Tunisia, and (9) Norway.

OBJECTIVE/PURPOSE: To assess the utility of Seasat and related data for offshore oil and gas drilling and production operations.

APPROACH: Seasat and related data will be obtained from NASA and utilized by the companies operating in the test area. The data will be archived, initiating a long-term data base on environmental conditions most favorable for planning and designing of operations and equipment. During operations, long-range forecasts will be utilized to minimize damage or interference of operations or equipment by unexpected environmental conditions. Seasat data will be compared with the surface truth data obtained in areas (1) and (2) above to (1) validate sensor capability, (2) evaluate forecasts (with Seasat input) with previously established forecasts generated by Getty and (3) determine potential benefits that can be accrued from a Seasat-type operational satellite system.

DATA REQUIREMENTS: Seasat GDR observations and SAR imagery, FNWC products and forecasts, and Nimbus data.

DATA FORMAT AND FREQUENCY: FNWC real-time data in tables, charts and graphs whenever available. Non-real-time data in hard copy or tape format compatible with UNIVAC 90/30 computer.

COMMUNICATIONS EQUIPMENT AND DATA DELIVERY: A 1200-baud Vadic modem and Tektronix terminal will be provided by Getty (Houston) for the receipt of data directly from FNWC. NASA will pay for the telephone line communications cost.

SURFACE TRUTH DATA: Getty collected surface truth data for areas (1) and (2) above during the life of Seasat on sea and air temperature, waves (height, period and direction), wind speed and direction and current speed and direction.

Worldwide Offshore Drilling and  
Production Operations Experiment

This experiment is being conducted by Getty Oil Company in cooperation with NASA for the purpose of evaluating the potential that Seasat and related satellite data have for affecting the decision processes that must routinely be made during their offshore drilling and production operations. Over the various ocean areas of the world, there are several test sites of potential interest to Getty. The remoteness of these areas has made the gathering of environmental data difficult, and the resulting lack of data has left drilling operations often unprepared for oncoming severe weather. The use of Seasat-type and related data to monitor local environmental conditions could not only reduce operator expenses but also contribute greatly to the safety of the drilling operations.

Getty Oil Company is currently operating or planning operations in nine areas worldwide, and has established the following priorities for these offshore test sites: (1) Ibiza Marino (Spain), (2) the Strait of Ontranto (Italy), (3) West Africa, (4) Northwest Australia, (5) U. S. East Coast, (6) Curacao, (7) Argentina, (8) Norway and (9) Tunisia. Getty will normally serve as operator of a drilling vessel in these areas under a joint venture enterprise. The prospective partners for each area of interest are listed in Table 1. Specific sites cannot be defined at this time but would be defined approximately 2 to 6 months prior to drilling in the areas of interest described in Table 1. Operations in a specific area will likely continue for a minimum of 3 months. The approximate areas of interest are shown in Figure 1.

It should be noted that with the failure of the Seasat satellite on 10 October 1978, any real-time or near-real-time data provided from then onward will be obtained from other satellites such as Nimbus, and the data products will be distributed by the Navy's Fleet Numerical Weather Central (FNWC) in Monterey, California. Consequently, the focus of future work using real-time data will be on establishing the viability of the data distribution system.

TABLE 1. GETTY PROSPECTIVE PARTNERSHIP DETAILS FOR WORLDWIDE OFFSHORE DRILLING AND PRODUCTION OPERATIONS EXPERIMENT

Area	Location	Prospective Partner	Host Government	Likely Period of Activity
Ibiza Marino, Spain	39-41°N, 1-3°E	Phillips Petroleum, Hispanica de Petroleos & AGIP	Spain	1978-1981
Straits of Ontranto, Italy	37°N, 15°E	-ditto-	Italy	1978
Offshore West Africa	0-12°N and 4-7°S; coast up to 2000-m isobath in longitude	"	Congo	1979
Northwest Australia	14-16°S, 124-126°E	Union Texas, CONOCO, Shell, Broken Hill Pty	Australia	1979-1980
U.S. East Coast	33-45°N, 70-75°W	Presently unknown	U.S.A.	1979-1981
Curacao	11-13°N, 67-69°W	Phillips Petroleum, Hispanica de Petroleos & AGIP	Curacao	1980-1981
Argentina	49-51°S, 64-66°W	-ditto-	Argentina	1980-1981
Norway	No coordinates as yet	Statoll, et al.(a)	Norway	1979-1981
Tunisia	36-38°N, 9-11°E	Presently unknown	Tunisia	1981

(a) Partners assigned by host government after lease sale.

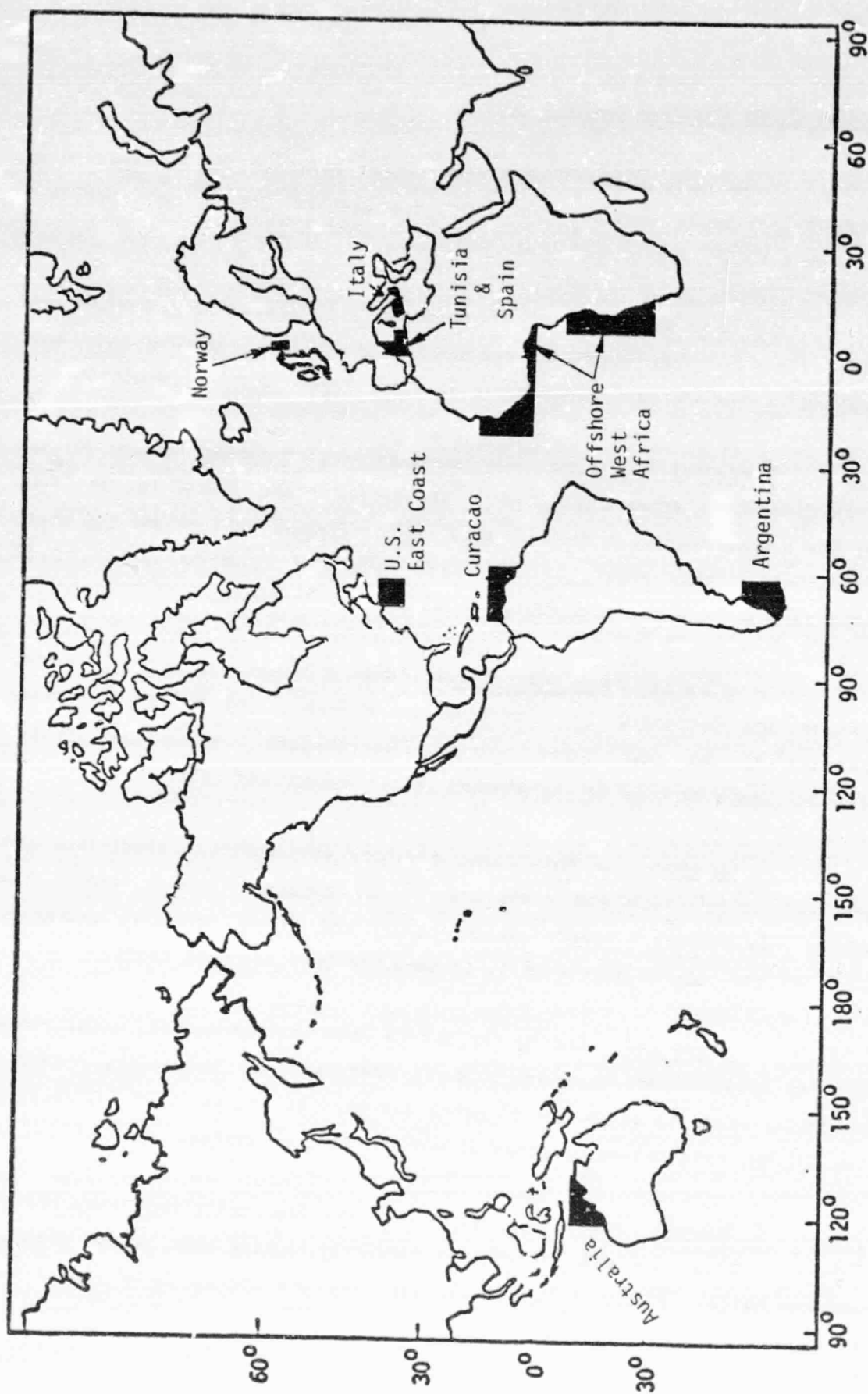


FIGURE 1. AREAS OF INTEREST FOR WORLDWIDE OFFSHORE DRILLING AND PRODUCTION OPERATIONS EXPERIMENT No. 5

### Summary of the Physical Environment

The environmental conditions (both averages and extremes) vary for each test site. Typical conditions for each of the future sites, are delineated in the paragraphs that follow.

Offshore West Africa. The weather in this area is generally less severe than in other areas of the world, but past operations have been hampered by unexpectedly large sea states and severe weather conditions.

Northwest Australia. The hurricane season during January through March (and diminishing through May) produces intense storms in the Timor Sea which move southwest through this area. Typical weather and sea state conditions in this area are not severe, although winds in excess of 35 knots associated with local disturbances are not uncommon.

Offshore U. S. East Coast. During winter and spring, weather systems are dominated by extratropical systems, and in the northern portions of the east coast, severe low pressure systems are likely. Tropical storm systems may be present in the summer and fall.

Curacao. In this area, offshore environmental conditions are generally mild, with the exception of the hurricane threat during the period July through October. During winter and spring, winds in excess of 35 knots and seas in excess of 12 ft occur on an infrequent basis.

Argentina. During the period June through August, local storm systems called "Pamperus" increase in frequency and intensity, commonly producing winds in excess of 40 knots and seas in excess of 15 ft. During the spring, cold season cyclones affect the weather system.

Norway. North Sea operations have frequently been hampered by severe weather and sea states, particularly during the period October through March. During this period, low pressure systems move across the

Atlantic and grow in intensity. Winds in excess of 60 knots are common for these storm systems. Recommended maximum design wave heights for 100-year recurrence intervals in this area are typically 30 meters. From July through September, local disturbances are common, but are not as severe as the winter low pressure systems.

Tunisia. Offshore Tunisia sea and weather conditions are characterized by 6-ft average wave heights and about 15-knot wind speeds. However, during storm conditions, waves in excess of 30 ft and wind speeds exceeding 50 knots occur about 2 percent of the year. It is important to anticipate the occurrence of such storms so that appropriate action can be taken and the risk of severe problems for operations can be reduced.

Spain. Offshore Spain climate conditions are somewhat less severe than those of Tunisia. Nevertheless, storm conditions and occurrences need to be known in advance. Average waves of 4 ft and a 12-knot wind speed are the mean for the year. Extreme storm conditions, typically 20-ft waves and a 50-knot wind speed, occur about 1 percent of the year (3 to 4 days per year).

#### Experiment Motivation

Getty and its potential partners have substantial financial interest in conducting the most efficient drilling operations possible in the designated areas. Operations are often conducted in remote locations where very little, if any, environmental data are available. If these data were available during the planning stage, operations could be organized either to take better advantage of good weather or to prepare for more severe weather.

During operations, local environmental conditions are monitored and ship response is properly compensated. Several environmental conditions which originate great distances from the area of operations, and which travel quickly into the area of operations, may not be detected sufficiently ahead of time to reduce the drillship's vulnerability to

movement. Severe tropical or subtropical storms and hurricanes, tidal waves, or tsunamis would be examples of environmental conditions which could yield substantial financial losses as well as affect the safety of the operation. Early warning of these conditions is sought.

#### Objectives/Purpose

The overall objective is to conduct drilling and, later, production operations in the most efficient, cost-effective manner. The specific objective of this experiment is to assess the utility of Seasat and related data for offshore hydrocarbon drilling and production operations.

#### Approach

The Seasat satellite failed on 10 October 1978, having yielded over 90 days of data which will be provided to Getty in non-real time in the form of Geophysical Data Records (GDR's) and synthetic aperture radar (SAR) data. The GDR's will be used in Getty's Seasat data evaluation case study to:

- (1) Validate sensor capability in company with surface truth
- (2) Evaluate the forecasting value of the sensor data by comparing them with forecasting reports previously generated by Getty
- (3) Assess the use of Seasat data in design (build an environmental data base).

Getty has no special SAR requirements for this experiment, since there were no data taken in the operating areas, and will be satisfied with copies of the SAR data provided to other experimenters for the offshore U. S. East Coast, Gulf of Mexico or the Beaufort Sea. Getty will then work with SAR data provided to become familiar with their use.

Estimates of expected winds, waves, and currents will be made for both the short term (for drilling operations) and long term (for production or other extended operations). The short-term forecasts are necessary to minimize damage or interference of operations due to unexpected



environmental conditions, whereas the long-term estimates provide a basis for design or equipment selection for extended operations. Real-time data (from FNWC) will be used for short-term forecasts; by appropriate selection, processing and archiving of these data, a long-term data base will be initiated and will be coupled with existing historical data, if any.

Available real-time data include FNWC products and some Nimbus satellite data. The real-time data obtained from FNWC will be processed and archived; at appropriate times these data will be compared to the drillship data (see section on surface truth data). A preliminary plan for the data processing, archiving and analysis scheme is shown in Figure 2. Data sets DS1 and DS2 will be compared at the conclusion of each drillship operation, or as available. At this point in time, the main objective in this area will be for Getty to evaluate the real-time data distribution system (telephone lines, terminals, etc.) rather than the accuracy of the real-time data per se.

Industry Data Requirements. NASA will provide Getty Oil Company with the following data:

- (1) Seasat Geophysical Data Records (GDRs), including altimeter ( $H_{1/3}$ ), scanning multifrequency microwave radiometer (SMMR) wind magnitude, Seasat-A scatterometer system (SASS) wind magnitude, and SMMR sea surface temperature.
- (2) FNWC products, which include:
  - (a) Analysis products of marine winds (magnitude and direction); sea surface temperature (SST); atmospheric pressure at sea level, 500, 700 and 850 mb;  $H_{1/3}$ ; primary wave period and direction; and spectral wave data
  - (b) Forecast products of those mentioned in Item (2) above except SST
  - (c) A preferred forecast period of 24 hr.
- (3) Nimbus data of winds and SST.

[illegible]

The minimum accuracy\* required by Getty for the altimeter data is  $\pm 1.5$  m, or 20 percent of the measured value. For the SASS data, the minimum accuracy required is  $\pm 5$  m/sec for wind magnitude and  $\pm 90^\circ$  for wind direction. Getty's SMMR minimum accuracy requirements for sea surface temperature data are  $\pm 1^\circ\text{C}$  relative and  $\pm 5^\circ\text{C}$  absolute. In all cases, the time period of interest is from 1 July to 10 October 1978. The priority in which the data are required is (1) wind, (2) waves and (3) temperature.

Additionally, Getty is interested in receiving a sample of synthetic aperture radar (SAR) passes for any of the areas in the Beaufort Sea, offshore U.S. East Coast or the Gulf of Mexico which are being reduced for the other experimenters.

Surface Truth Data. Getty Oil Company currently has available environmental data measured on the "Discoverer Seven Seas" drillship during July to October 1978. Located off Ibiza Marino (Spain) from July 1 to July 23, and then in the Strait of Ontranto (Italy) from August 3 to October 1, the drillship measured and recorded the data on magnetic tapes from the Honeywell ASK system continuously in 1-sec increments. Available data include wind speed and direction, wave elevation, and current speed and direction, as detailed further in Table 2. These surface truth data will be used in a comparative analysis with the Seasat and related data.

#### Data Format and Communication Equipment

The format of the Seasat and related data products should be as follows:

- (1) Tabular/tape with simplified graphic display for GDRs
- (2) SAR imagery on film transparencies and positives as well as computer-compatible tapes (CCT) of 10 percent of imagery.

The FNWC products format should be tabular/tape and graphics with isopleths, coordinates and land masses; standard contour intervals should

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\*If possible and when available, Getty would like to receive copies of Seasat data at better accuracies than those listed as minimum.

TABLE 2. SURFACE TRUTH DATA SUMMARY FOR SEASAT COMMERCIAL DEMONSTRATION EXPERIMENT NO. 5

Parameter/Observation	Obs. Platform (Vessel, A/C, Platform, Buoy)	Instrumentation (Baron, Anemom., Thermos, Visual Obs.)	Location	Observation Dates (1978)	Frequency of Observation
Wave Height	"Discoverer Seven Seas" drillship	Waverider buoy several hundred feet away from ship; WAREP-type ocean res. equipment	(1) 39°N, 1°E: Ibiza Marino, Spain (2) 37°N, 15°E: Strait of Ontranto, Italy	July 1-23 Aug 3-Oct 1	Continuous at 1-sec intervals
Sea Surface Temperature	-ditto-	TBD	(1) 39°N, 1°E: Ibiza Marino, Spain (2) 37°N, 15°E: Strait of Ontranto, Italy	July 1-23 Aug 3-Oct 1	TBD
Wind Speed & Direction	"	-ditto-	(1) 39°N, 1°E: Ibiza Marino, Spain (2) 37°N, 15°E: Strait of Ontranto, Italy	July 1-23 Aug 3-Oct 1	Continuous at 1-sec intervals
Ice Conditions	TBD	"	Beaufort Sea*	Summer 1978	TBD
Current Speed & Direction	"Discoverer Seven Seas"	Acoustic type, TBD	Location (1) above and Location (2) above	-ditto-	-ditto-

Note: Data are recorded on magnetic tapes from the Honeywell "ASK" system. They can be averaged out at more suitable intervals upon request.

\*Gatty has Beaufort Sea data which they are willing to provide for the use of other experimenters.

be observed. The map projection could be either Mercator or Polar stereographic, depending on the latitude of the specific test area involved.

The near-real-time data will be transmitted through the FNNC computer system to Getty Oil Company in Houston through a Tektronix terminal once per day between the hours of 8 and 5 Central Daylight Time. NASA will pay for the cost of the telephone lines.

#### Reporting and Schedule

Guidelines for reporting the experiment results are given in the paragraphs that follow.

Progress Reports. Battelle will submit periodic progress/status reports to NASA HQ. It is expected that the experimenter will provide inputs for these progress reports, but this is not a formal requirement. Battelle will provide the experimenter with copies of all such reports submitted to NASA.

Final Report. A final report (one camera-ready copy and four bound copies) will be prepared by the experimenter upon completion of the experiment, but not later than December 31, 1980. It is suggested that this report be prepared for general dissemination in accordance with good reporting practice. It may include experiment objectives, experiment description, techniques and procedures employed for the data analysis and assessment, conclusions, and recommendations. Also desirable is the experimenter's assessment of the results in terms of:

- (1) Potential contribution of Seasat-type data to the experimenter's future needs
- (2) Characteristics of an operational satellite system that are of importance to the users.

Schedule. A planning schedule for this worldwide offshore drilling and production operations experiment is shown in Figure 3.





**EQUATORIAL EAST PACIFIC OCEAN MINING**

**(ASVT EXPERIMENT 6)**

**NASA/DEEPSEA VENTURES, INC., KENNECOTT EXPLORATION, INC.,  
INCO UNITED STATES, INC., AND OCEAN MINERALS COMPANY**

**COOPERATIVE EXPERIMENT PLAN**

**July 1978**

**AMENDMENT 1**

**MARCH 1979**

**NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
Office of Space and Terrestrial Applications  
Washington, D. C. 20546**

## EXPERIMENT SUMMARY

ASST EXPERIMENT: No. 6

TITLE: Equatorial East Pacific Ocean Mining

EXPERIMENT REPRESENTATIVE/ORGANIZATIONS: (Bill Siapno) Deepsea Ventures, Inc., Gloucester Point, VA 23062. Telephone: (804) 642-2121; (A. Steen) Kennecott Exploration, Inc., 11095 Flintkote Ave., San Diego, CA 92121. Telephone: (714) 453-3751; (John L. Shaw) INCO Limited, 1 New York Plaza, New York, N.Y. 10004. Telephone: (212) 742-4381; Ocean Minerals Company, joint venture represented by (F. T. Lovorn) Lockheed Ocean Laboratory, 3380 North Harbor Drive, San Diego, CA 92101. Telephone: (714) 298-8245.

COORDINATOR: (A. George Mourad) Battelle's Columbus Laboratories, 505 King Avenue, Columbus, OH 43201. Telephone: (614) 424-5097.

EXPERIMENT LOCATION: Area included within 5°-20°N; 110°-150°W plus storm area of the west coast of North America between 5°-40°N and out to 150°W.

OBJECTIVE/PURPOSE: To assess Seasat and related sensor data utility for ocean mining design, exploration and operations.

APPROACH: The ocean mining consortia will acquire Seasat data and conduct case study evaluations by comparing data with on-site measurements made by instrumented vessels to establish their reliability and usefulness for mining operations. In addition, Seasat data will be used as input for preparing forecasts for selected periods during hurricanes and severe storms and compared with existing conditions at that time. FNWC products and Nimbus data will be received in real time during mining ship operations and will also be evaluated primarily to determine the capability and effectiveness of a real-time satellite data distribution system.

DATA REQUIREMENTS: Real-time data to include some Nimbus observations, and FNWC products and forecasts. Non-real-time data to include (1) seven SAR passes during storm activities and (2) Seasat GDR observations.

DATA FORMAT AND FREQUENCY: Real-time data in tables, charts and graphs twice per day, preferably in the morning and early evening hours through Station WWD. Non-real-time data, except SAR, on magnetic tapes. SAR imagery as transparencies or film positives.

COMMUNICATIONS EQUIPMENT AND DATA DELIVERY: Radio fax equipment will be provided by the operating companies' ships for receipt of real-time data. Station WWD, which will receive data on fax and retransmit plots to fisheries, will also transmit for the mining ships. Kennecott requirements for FNWC and Nimbus data will be obtained on magnetic tapes from Station WWD if WWD archives such data; otherwise, NASA will provide Nimbus data to Kennecott.

SURFACE TRUTH DATA: Deepsea Ventures and Ocean Minerals were operational during the life of Seasat and will have surface truth data on winds, waves, temperature and atmospheric pressure. The other consortia were not operational.



### Equatorial East Pacific Ocean Mining Experiment

This experiment is being conducted by the members of three ocean mining consortia in cooperation with NASA for the purpose of evaluating the potential that Seasat and related satellite data have for affecting the decision processes that must be made during ocean mining design, exploration and operations. The fourth consortium, INCO Limited, is in the process of reorganizing and may participate at a later date.

Minerals are the lifeblood of our industrial society. While land deposits of many vital minerals are dwindling, world population and expectations are rising at an unprecedented rate, making it imperative to develop new sources of supply for vital metals. Nodules lying on the deep ocean floors are a rich source for four of these metals: copper, nickel, cobalt and manganese, and this potential has prompted technological development in deep ocean mining during recent years. All four of these metals are essential to our economy, with manganese being essential for steel production.

The equatorial east Pacific Ocean is of prime interest to the ocean mining industry. Four consortia, Deepsea Ventures Inc., Kennecott Exploration Inc., INCO Limited, and Ocean Minerals Company, have expressed a strong interest and outlined their combined needs and verification capabilities for this area. Deepsea Ventures is the operator for Ocean Mining Associates which is composed of: (1) U.S. Steel, (2) Sun Company, Inc. and (3) Union Miniere. Kennecott Exploration is operator for a joint venture composed of: (1) Mitsubishi Corp. (Japan), (2) Noranda Mines Ltd. (Canada), (3) Rio Tinto Zinc (U.K.), (4) Consolidated Goldfields (U.K.), (5) British Petroleum (U.K.) and (6) Kennecott Copper Corp. INCO is operator for Ocean Management, Inc., which is composed of: (1) INCO United States, Inc., (2) AMR (German), (3) DOMCO (Japan) and (4) Sedco. Ocean Minerals Company is operator for a joint venture composed of: (1) Lockheed Aircraft Company, (2) Billiton Minerals International, (3) BOS Kalis Westminster (Netherlands), and (4) AMOCO Minerals Company.

Basically, two test areas are of interest: a mining area and a storm area. Data requirements of each are similar, but with differences of emphasis. The general location of the test areas encompasses offshore southern California and Central America in a corridor 15 degrees wide extending to southeast of Hawaii. The mining area, a region of high-grade and abundant module material, is located in the northeast equatorial Pacific and is defined by the boundaries 5° to 20° north latitude, and 110° to 150° west longitude, as indicated on Figure 1. Storms in the area originate about the Gulf of Tehuantepec. Historically, an average of 28 storms develop each year and then proceed on either a northwesterly track or a westerly track which passes through the mining area. Accordingly, the storm area is defined as the region encompassing the mining area extended as shown on Figure 2.

Industry currently has environmental data taken from two mining ships operating in the test area that will be used to determine the applicability and benefit of Seasat data for establishing design and operational criteria for deep ocean mining systems. With the failure of the Seasat satellite on 10 October 1978, any real-time or near-real-time data provided by NASA from then onward will be obtained from other satellites such as Nimbus, and the data products will be distributed by the Navy's Fleet Numerical Weather Central (FNWC) in Monterey, California. As a result, the focus of future work will be on establishing the viability of the real-time data distribution system.

#### Summary of the Physical Environment

The mining area is typified by a relatively benign environment. Mean significant wave height is approximately 5 feet, while wind velocities are typically 10 to 15 knots. Late spring and early summer are the calmest periods; winter months are typified by unstable conditions, with localized squalls or depressions occurring suddenly, although of short duration. During summer and fall, tropical storms will pass through the mining area. Associated wave heights may be as great as 50 to 60 feet, and wind velocities may be in excess of 64 knots.

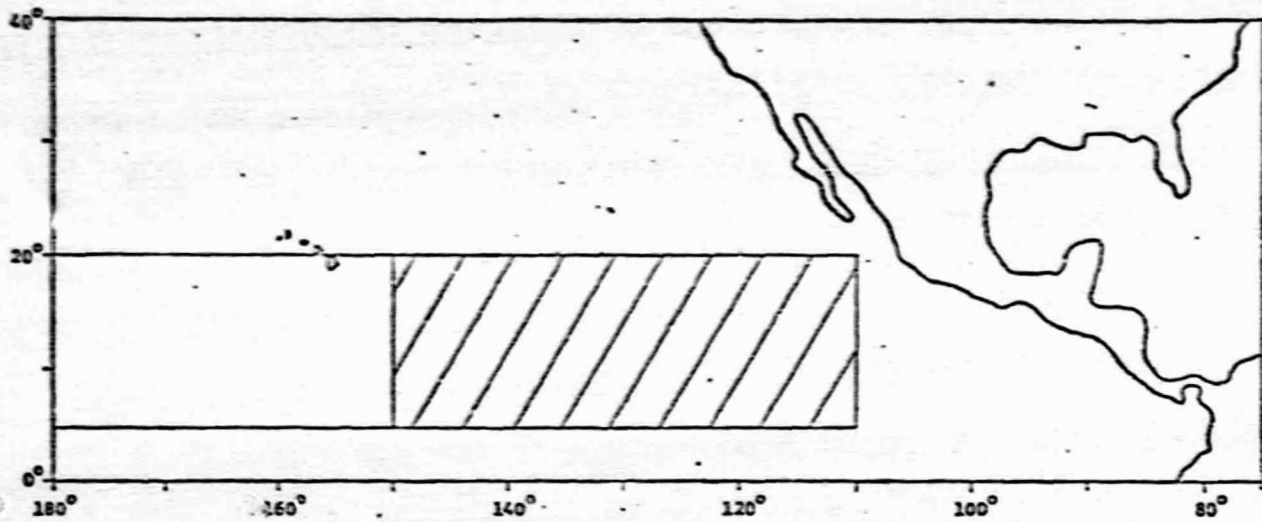


FIGURE 1. PROPOSED TEST MINING AREA

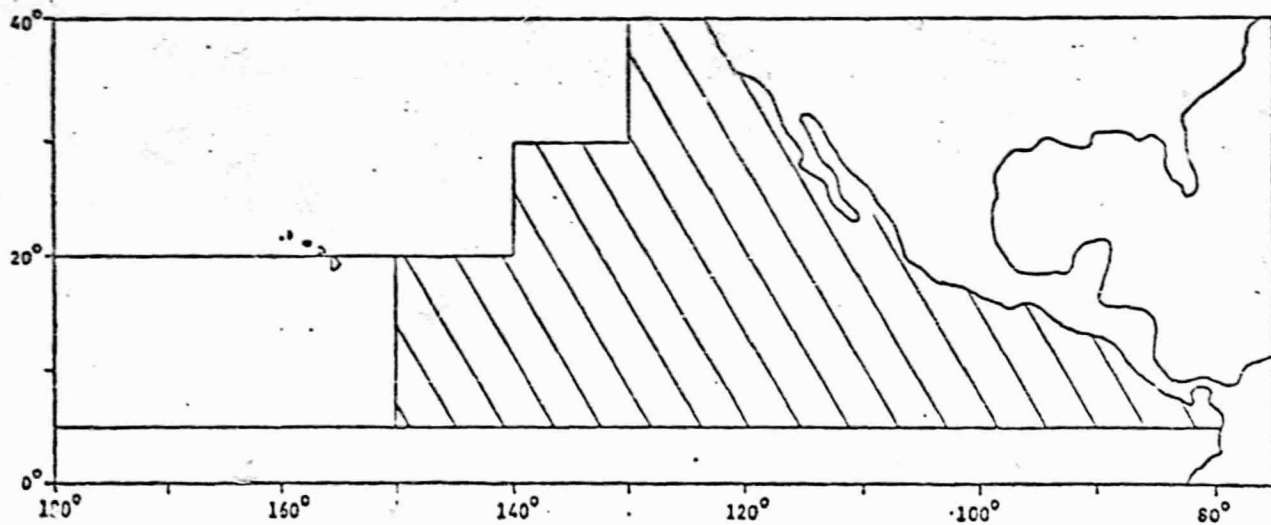


FIGURE 2. STORM AREA INFLUENCING PROPOSED TEST MINING AREA

The storm season is basically limited to the months of June through October. Tropical storms are categorized by wind velocities of 34 to 64 knots, while hurricane winds are in excess of 64 knots. Examples of each are observed every year, with tropical storms occurring about twice as frequently as hurricanes. Development time is 6 hours to 4 days, longer development being associated with more intense storms. Storm/hurricane life is variable, 2 to 15 days.

#### Experiment Motivation

Currently, three of the ocean mining consortia are actively involved in exploration, design, and development of mining systems which will efficiently exploit mineral resources of the equatorial Pacific. The four consortia represent about a \$2 billion industry in initial capital expenditures with operating costs expected to approach \$400 million per year. Numerous aspects of the mining system are advancements in the state of the art. As such, they are unproven and susceptible to the cumulative effect of design uncertainties, of which the environment and its prediction are significant. To minimize overdesign, the extent of post-design modifications, and otherwise permit more effective use of economic resources, accurate description of the operating environment is essential.

Results of the study will benefit the following areas:

- (1) System Design. The region of ocean mining operations is outside normal trade routes and typified by a limited amount of historical data. Uncertainty in the statistics of various sea conditions has necessitated a conservative design approach. Information measured by Seasat will help minimize design uncertainties and permit a more adequate and realistic design.
- (2) Improved Operations Plan. The sequence of mining operations and alternatives is to a large extent controlled by real time and anticipated environmental conditions. Inaccurate predictions may result in system unavailability due to lost equipment or costly false alarm delays. The evaluation of



data accuracy and reliability will aid in defining an optimum operations plan and eliminate unnecessary contingencies.

- (3) Logistics. Bulk carriers will be used to transport mined material between the operations site and port facilities and for the replenishment of consumables. Continuous operations require that the transport vessels closely follow a given schedule. The identification of severe environmental conditions, their location and predicted movements will allow weather rerouting to minimize delays and permit efficient operation of the transport vessels and mining ship.
- (4) Evaluation of Predictor Models. The National Weather Service Forecast Office in Redwood City, California, provides general forecasts of weather conditions including waves/swells, winds, and precipitation. The National Oceanic and Atmospheric Administration (NOAA) in Washington, D.C., has developed a model for predicting the likelihood of storm genesis, and following genesis, the predicted track and associated intensity of the storm. Data from Seasat will be intensity applied as initial input, update, and for subsequent verification of the predictor model performance.

#### Objectives/Purpose

The overall objective is to assess the utility of Seasat data for ocean mining design, exploration and operations. The specific objectives are to:

- (1) Conduct case study analysis and evaluation of Seasat-type data by comparing them with surface truth data and determine their utility in predicting hurricanes and severe storm conditions
- (2) Establish a historical data base and evaluate its utility for the design of second-generation ocean mining systems and in quantifying persistence information such as duration of

waves of a particular height and the time interval between such wave conditions.

#### Approach

The Seasat satellite failed on 10 October 1978, having yielded over 90 days of data which will be provided to members of the mining consortia in non-real time in the form of Geophysical Data Records (GDRs) and synthetic aperture radar (SAR) data. The GDRs and available real-time and near-real-time data obtained from FNWC will be used in satellite data evaluation case studies to validate sensor capability, evaluate the data distribution system, and determine the forecasting value of the sensor data; however, at this point in time, the main objective will be for the operating consortia to evaluate the real-time data distribution system rather than the accuracy of the real-time data per se.

Effectively, all phases of ocean mining operations are governed by sea and atmospheric conditions. Efficient operations require close monitoring of the ocean environment and necessitate accurate information and reliable weather predictions. Thus, Seasat data and FNWC products will be collected by the operating companies together with all other reliable information available to the mining industry and processed into a suitable, ready-to-be-used format. On-site surface truth data will be collected from instrumented vessels operating at the time and from visual observations, and will be compared with satellite data.

In view of the Seasat data available between July and October 1978, three ocean mining consortia\* will conduct case studies employing the Seasat GDRs and SAR imagery with the ultimate objective of establishing a severe weather forecasting capability using Seasat-type satellite data. It is of particular significance that near record hurricanes occurred in the July-September 1978 period; thus, the Seasat data should serve as excellent input to a severe weather forecasting scenario. The intent of the case

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\*Inco Limited, which already demonstrated the feasibility of ocean mining, is in the process of re-examination of its future efforts and will decide on participation at a later date.

study is to provide the meteorological scenario from whatever source data may be available and to determine the enhancement that is possible by adding Seasat survey data. In this way, parametric evaluation of satellite-collected information of mid-ocean areas would be readily understandable. The study will be conducted in two phases:

- Phase I involves three manipulations of the non-real-time data available from Seasat in order to establish the validity of the data:
  - Analyze the data (including wind, waves, sea surface temperature, and SAR passes)
  - Prepare an environmental forecast (in hindsight) using the Seasat data
  - Validate the forecast and the data used by comparing the forecast results with actual environmental conditions at that time in the past.
- Phase II will employ the real-time data available from FNWC to forecast environmental conditions in the test area; Station WWD will begin transmitting the data to Deepsea Ventures and Ocean Minerals who will be operating during 1979; Nimbus data will be included. This will provide a major opportunity to evaluate the data distribution system -- its timeliness, reliability, flexibility, etc. Kennecott and INCO will participate when they become operational.

The mining area, being outside normal trade routes, is typified by a scarcity of environmental data. Wave and wind data from the Seasat program will be used in augmenting a relatively scant data base and, in addition, supply data which are consistent and objective rather than the subjective interpretation of individual operators. Also, Seasat and related data will be used in statistical studies for quantifying persistence information such as duration of waves of a particular height and the time interval between such wave conditions.

Although the operational life of Seasat did not supply a sufficiently long time span of data to satisfy a statistician's requirements, it will, nevertheless, be quite useful, given current data scarcity. In

this light, Seasat and related satellite data will be evaluated to determine their utility in planning activities which are dependent upon knowing future data availability as well as providing an adequate data base for a second-generation deep ocean mining system.

The limited SAR passes obtained from NASA during storm activities will be compared with surface truth data to establish the validity of sensor capability. Assessment will then be made of the utility of SAR images for measuring storm size, intensity and path for forecasting purposes.

Due to the requirements of individual consortia to maintain confidentiality with respect to their areas of operations, each participating consortium reserves the right to individually process, compare, and evaluate consortium interests and provide a basis for accurate evaluation of Seasat capabilities. Information collected by the consortia will serve to verify information provided by Seasat. The results of comparison, analysis and evaluation, as well as benefits of Seasat-type data to ocean mining, and recommendations concerning future operational systems, will be documented in a final report that will be furnished to NASA.

Industry Data Requirements. NASA will provide the individual operating consortia with the following data:

- (1) Seasat Geophysical Data Records (GDRs) including altimeter ( $H_{1/3}$ ), scanning multifrequency radiometer (SMMR) wind magnitude and sea surface temperature, and Seasat-A scatterometer system (SASS) wind magnitude and direction.
- (2) Synthetic aperture radar (SAR) imagery: 7 passes.
- (3) FNWC products, which include:
  - (a) Analysis products of wind, pressure field at sea level,  $H_{1/3}$ , primary wave period and direction, and spectral wave data
  - (b) Forecast products of pressure field at sea level, wind speed and direction,  $H_{1/3}$ , primary wave direction and period and spectral data



(c) Observation files of sea level pressure and upper air measurements

(d) All forecasting periods (12, 24, 48 and 72 hr) are required, with priority for the 12-hr period.

(4) Nimbus data of wind and temperature.

The minimum accuracy required\* by the consortia for the altimeter data is  $\pm 1$  m or 25 percent of the measured value. For the SASS data, the minimum accuracy required is 20 percent of the measured value for wind magnitude and  $\pm 30^\circ$  for wind direction. Their SMMR minimum accuracy requirements for sea surface temperature data are  $\pm 2^\circ\text{C}$  relative. In all cases, the time period of interest is from 1 July to 10 October 1978. The priority in which the data are required is (1) wind, (2) waves and (3) temperature.

Quality image products of synthetic aperture radar (SAR) passes are needed. The consortia require a minimum of three passes, but would prefer seven passes taken during tropical storm activities in July and August 1978 in an area bounded by  $5\text{--}20^\circ\text{N}$  latitude and  $210\text{--}250^\circ\text{E}$  longitude; specifically, in order of priority, they have selected the following passes, with desired SAR ground swath end points of  $12.5^\circ\text{N}$  latitude on and  $20^\circ\text{N}$  latitude off for Passes #17 and #24, and  $15^\circ\text{N}$  latitude on and  $22^\circ\text{N}$  latitude off for Pass #7:\*\*

- Pass ID #17, rev 222, on 7/12/78
- Pass ID #24, rev 251, on 7/14/78
- Pass ID #7, rev 179, on 7/9/78
- Pass ID #8, rev 186, on 7/10/78
- Pass ID #35, rev 308, on 7/18/78
- Pass ID #65, rev 430, on 7/27/78
- Pass ID #144, rev 674, on 8/13/78.

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\* Experiment representatives would like to ultimately receive Seasat data to much better accuracy than the minimum required.

\*\*The first three passes listed are on the NASA highest priority list for processing; the remaining four passes have been requested by the experimenter, and NASA will consider processing them on a non-priority basis.

Surface Truth Data. Surface truth data will be gathered by consortia vessels operating in the test area at the time of the experiment. These vessels will serve as platforms for meteorological and oceanographic observations, and instrumentation on the vessels will consist of the following systems:

- Anemometers -- true wind speed and direction
- Thermometers
- Dew point may be provided, if needed
- Barometer.

Additional systems on some of the vessels may include:

- Waveriders
- Accelerometers
- Current meters.

Some systems will gather complementary information to provide cross-checks, minimize possible errors and thereby provide more accurate and reliable data. In addition, human observations will be made to provide correlation between observed and measured data.

On-site measurements, observations, and comments will be transmitted to the appropriate receiving agency on a day-by-day basis. A summary of all data collected and/or evaluated will be provided after the end of the test period.

Deepsea Ventures currently has available environmental data measured during July and September 1978 on a mining ship at the test site. Particulars as to instrumentation, observation dates and frequency are presented in Tables 1 and 2.

Details of the Deepsea Ventures operating schedule and facilities for surface truth data are as follows:

- (1) R/V PROSPECTOR is expected to be on station on a scheduled basis, not continuous, through calendar year 1979. Schedules beyond that date are yet to be formulated. Very possibly R/V DEEPSEA MINER II will be in the area sporadically during this period.

TABLE 1. JULY DEEPSEA VENTURES SURFACE TRUTH DATA SUMMARY  
FOR SEASAT COMMERCIAL DEMONSTRATION EXPERIMENT NO. 6

Parameter/Observation	Obs. Platform (Vessel, A/C, Platform, Buoy)	Instrumentation (Eatom, Anemom, Thermom, Visual Obs.)	Location	Observation Dates (1978)	Frequency of Observation
Wave Height, Direction and Swell	R/V Prospector Mining Ship	Visual estimates	14°-15°N, 125°-126°W	June 30-July 20	Once every 6 hours
Sea Surface Temperature	-ditto-	Bucket	-ditto-	-ditto-	-ditto-
Wind Speed and Direction	"	Aerovane anemometer (U.S. Weather Bureau) Bendix Frieze model	"	"	"
Air Temperature	"	Taylor mercury thermometer	"	"	"
Pressure	"	Barometer (U.S. Weather Bureau) Bendix Frieze model	"	"	"
Storms & Visibility	"	Visual	"	"	"

Note: Six salinity/temperature/depth curves from 0 to 750-m depths are available for July 13 and 14, 1978.

TABLE 2. SEPTEMBER DEEPSEA VENTURES SURFACE TRUTH DATA SUMMARY  
FOR SEASAT COMMERCIAL DEMONSTRATION EXPERIMENT NO. 6

Parameter/Observation	Obs. Platform (Vessel, A/C, Platform, Buoy)	Instrumentation (Barom, Anemom, Thermom, Visual Obs.)	Location	Observation Dates (1978)	Frequency of Observation
Wave Height, Period and Direction	Mining Ship R/V Prospector	Visual	En route* 15°N, 125°W	Sept 8-11 and Sept 27-Oct 1 Sept 12-Sept 26	Once or twice per day depending on orbit selection
Sea Surface Temperature	-ditto-	Bucket	-ditto-	-ditto-	Once or twice per day
Wind Speed and Direction	"	Aerovane anemometer (U.S. Weather Bureau) Bendix Frieze model	"	"	20 min; 1-1.5 in averages; once or twice per day
Air Temperature	"	Taylor mercury thermometer	"	"	Once or twice per day
Pressure	"	Barometer (U.S. Weather Bureau) Bendix Frieze model	"	"	-ditto-
Radar Scope Photography Visibility/Clouds Swell	"	?	"	"	"

\*En route from San Diego to mining site, and back, on a great circle/rhumb line.

- (2) The locations at which such vessels will be operating are within the bounds of the following coordinates:

NE Corner Lat. 15°44'N Long. 124°20'W

NW Corner Lat. 15°44'N Long. 127°46'W

SW Corner Lat. 14°16'N Long. 127°46'W

SE Corner Lat. 14°16'N Long. 124°20'W

In general, they are more nearly expected to be in proximity to 15°N 125°W.

- (3) The instrumentation on board vessels would permit collection of wind speed and direction, wave height and direction, free air temperature (sea surface), and surface water temperature and water temperature down to approximately 700 meters.

Details of the Kennecott operating schedule and facilities are as follows:

- (1) Kennecott Exploration, Inc., did not operate any vessels during 1978. Plans for 1979 and 1980 are uncertain; as a result, a vessel cannot be named at this time.
- (2) The location of the vessel during operations is highly proprietary. In general, it will operate between 110°-150°W longitude and 5°-20°N latitude.
- (3) The period of operation can be any time during the year, but more likely during the late spring and the summer months. Operations will probably span three months, with activity on site three weeks out of four.
- (4) Instrumentation will include:
- (a) Anemometer giving true wind speed and direction
  - (b) Waverider buoy or accelerometer to obtain wave height, period and direction augmented by visual observations
  - (c) Thermometer to measure air/sea temperatures
  - (d) Barometer.
- (5) Vessel will be equipped to give instantaneous as well as 10-minute average wind speed and direction.



Details of the INCO schedule and facilities are uncertain at present. INCO has successfully demonstrated the feasibility of ocean mining through their deep-ocean pilot mining test. It is not yet known whether or when the INCO consortium or any of its individual members will go into full production operations. When this is established, detailed information on their vessels and surface truth data will be supplied.

Details of the Ocean Minerals operating schedule and facilities for surface truth data are as follows:

- (1) R/V GOVERNOR RAY will be operated in the experiment area during 1978 and 1979. There is also the possibility that the GLOMAR EXPLORER be in the area in late 1979 or 1980.
- (2) The location at which such vessels will be operating lies within the bounds of the coordinates 110°-160°W and 5°-20°N, and is known as the Clarion Clipperton Zone.
- (3) Vessel instrumentation will include:
  - (a) Anemometer, giving true wind speed and direction
  - (b) Barometer, for pressure readings
  - (c) Thermometer, to measure sea surface temperature.
- (4) It is possible to transmit data in real time, if desired, but it should be noted that vessel location is highly sensitive information.

#### Data Format and Communications Equipment

The format of the Seasat and related data products should be as follows:

- (1) Tabular and graphic GDRs for real-time data and 9-track computer-compatible tapes (CCTs) for non-real-time GDRs. It is desired by Kennecott that the tapes be compatible with a HP-2100 or PDP-11 computer system, if possible.
- (2) SAR imagery on film transparencies or positives for all passes and CCTs of 10 percent of the imagery.

The FNWC product format should be in graphics with isopleths and coordinates identified. Contour intervals will be standard available formats. Mercator is the preferred map projection for presentation of FNWC products.

Real-time data will be transmitted to WWD radio facsimile (fax) station in La Jolla, California. Personnel from the Marine Fisheries Services will receive Nimbus and FNWC data products and rebroadcast them over Station WWD to tuna and salmon boats; also, plans are being made to include the mining ships that are equipped with radio fax to receive such data once or twice per day at 8:00 a.m. and 4:00 p.m. PST.

Non-real-time data requirements for Kennecott will be obtained from Station WWD if WWD archives the data; otherwise, NASA will provide such data to Kennecott. NASA will pay for the cost of the telephone data transmission lines whenever applicable.

#### Reporting and Schedule

Guidelines for reporting the experiment results are detailed in the paragraphs below.

Progress Reports. Battelle will submit periodic progress/status reports to NASA HQ. It is expected that the experimenter will provide inputs for these progress reports, but this is not a formal requirement. Battelle will provide the experimenter with copies of all such reports submitted to NASA.

Final Report. A final report (one camera-ready copy and four bound copies) will be prepared by the experimenter upon completion of the experiment, but not later than December 31, 1980. It is suggested that this report be prepared for general dissemination in accordance with good reporting practice. It may include experiment objectives, experiment description, techniques and procedures employed for the data analysis and

assessment, conclusions, and recommendations. Also desirable is the experimenter's assessment of the results in terms of:

- (1) Potential contribution of Seasat-type data to the experimenter's future needs
- (2) Characteristics of follow-on systems that are of importance to the users.

Schedule. A planning schedule for this experiment in the Equatorial East Pacific is shown in Figure 3.



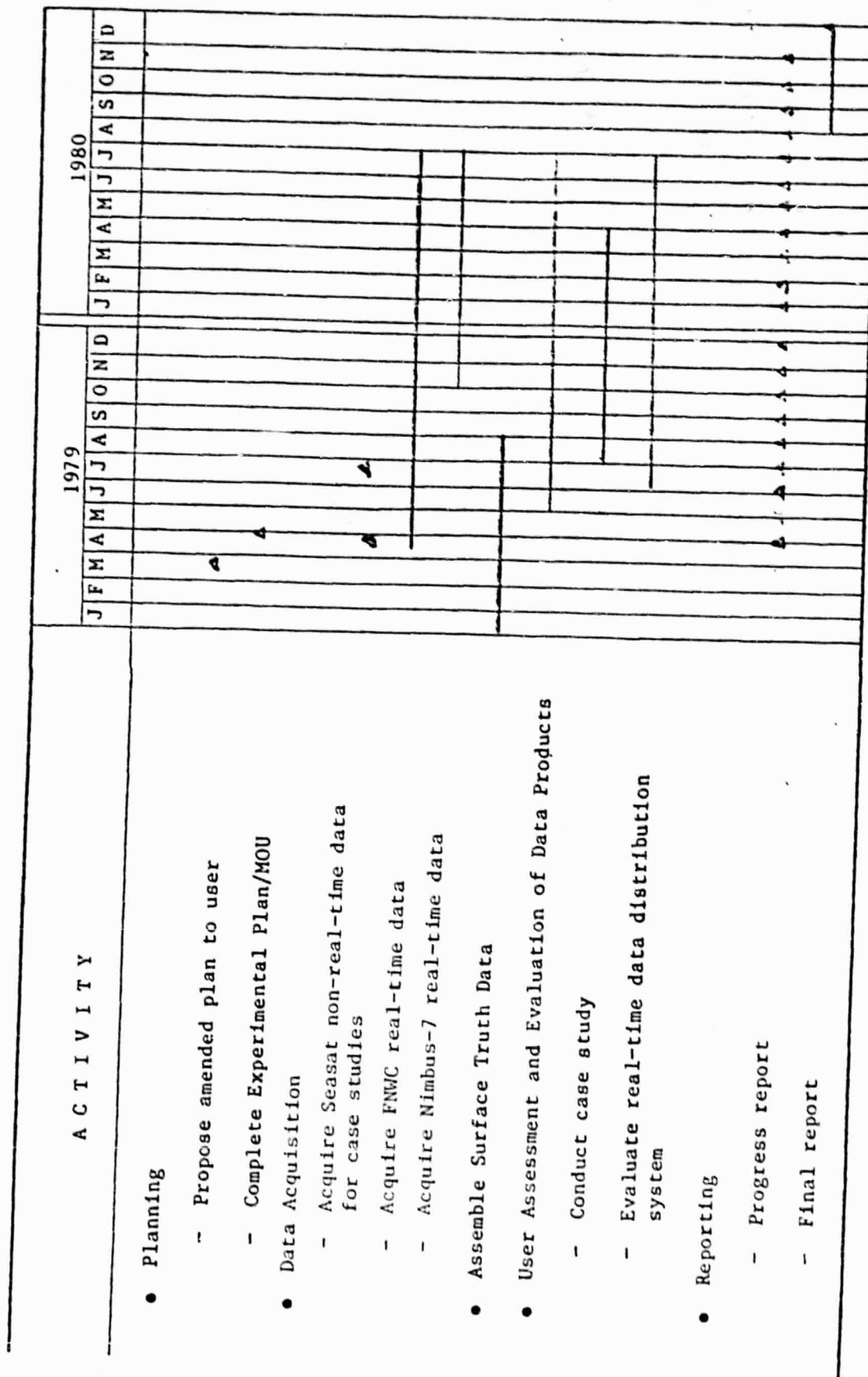


FIGURE 3. PLANNING SCHEDULE FOR EQUATORIAL EAST PACIFIC OCEAN MINING EXPERIMENT



BERING SEA ICE PROJECT

(MODIFIED SEASAT ASVT EXPERIMENT # 7)

NASA/OCEANOGRAPHIC SERVICES, INC.  
(ALASKA OIL & GAS ASSOCIATION PROJECT # 52)

JULY 1979

ORIGINAL PAGE IS  
OF POOR QUALITY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
Office of Space and Terrestrial Applications  
Washington, D. C. 20546

## EXPERIMENT SUMMARY

ASVT EXPERIMENT: No. 7

TITLE: Bering Sea Ice Project

EXPERIMENT REPRESENTATIVE/ORGANIZATION: Douglas C. Eckert, Oceanographic Services, Inc., 135 E. Ortega Stree, Santa Barbara, CA 93101; Telephone: (805) 963-1864/965-6575

COORDINATOR: Dr. Richard T. Gedney, NASA Lewis Research Center (LeRC) 21000 Brookpark Road, Cleveland, OH 44135. Telephone: (216) 433-4000, Ext. 209; and A. George Mourad, Battelle's Columbus Laboratories, 505 King Avenue, Columbus, OH 43201. Telephone: (614) 424-5097.

EXPERIMENT LOCATION: The U.S. Bering Sea between 58°N - 66°N as indicated on Figure 1.

OBJECTIVE/PURPOSE: To assess Side Looking Airborne Radar (SLAR) and Nimbus-7 Scanning Multichannel Microwave Radiometer (SMMR) imagery for assisting offshore petroleum operations on ice-covered areas in the Bering Sea. This experiment is a substitute for the one previously planned using Seasat sensor data. The basic intent of the experiment is the same as the original Seasat experiment; i.e., an assessment of microwave remote sensing for offshore operations in the Bering Sea.

APPROACH: Oceanographic Services, Inc. (OSI) will obtain truth data and compare them with aircraft imaging radar and Nimbus-7 SMMR data in the test area. Data reduction and analysis will focus on describing the ice conditions identifiable by these microwave sensors to determine type, distribution, motion and percentage of coverage. The results of comparison and evaluation will be described in a report to NASA. An assessment of the utility of the sensor data to various offshore operations and of the desirable characteristics for future operational ice information systems will be provided by OSI.

DATA REQUIREMENTS: NASA LeRC will provide X-band real aperture SLAR imagery for 3 days in March 1979. The NASA Environmental Data Center at Goddard Space Flight Center (GSFC) will provide Nimbus SMMR data throughout the experiment duration.

DATA FORMAT: SLAR and SMMR imagery on prints, negatives and computer compatible tape (CCT).

COMMUNICATIONS EQUIPMENT AND DATA DELIVERY: No requirements for communications equipment. Data delivery location is Oceanographic Services, Inc.

TRUTH DATA: Industry will acquire aerial photographic data and visual observations coincident with the acquisition of some of the microwave sensor data. Industry will use this truth data for assessing the capability of the sensor data.

## BERING SEA ICE PROJECT

### Introduction

The Seasat-A Program was conducted to test the concept of measuring characteristics of the ocean surface with satellite remote sensors. As part of the Seasat Industrial Experiment Program a Bering Sea Ice Project was planned to be conducted by Oceanographic Services, Inc. (Alaska Oil and Gas Association Project # 51) to evaluate the utility of the Seasat-A sensors for offshore oil and gas operations in the Bering Sea. Because no Seasat sensor data was acquired during the time when ice cover exists in the Bering Sea the planned Seasat-A experiment could not be performed. The Bering Sea experiment described herein using Side Looking Airborne Radar (SLAR) imagery and Nimbus-7 Scanning Multichannel Microwave Radiometer (SMMR) imagery is being substituted for the previously planned Seasat-A experiment. The basic intent of the new experiment is the same as the old experiment; i.e., and assessment of microwave remote sensing capabilities for offshore operations in the Bering Sea.

The areas of interest include the Bering Sea between  $58^{\circ}$  -  $66^{\circ}$ N and east of the U.S. - Soviet border as shown in figure 1.

### Experiment Motivation

The major incentive for this experiment stems from the oil industries need for ice information in the Bering Sea. The capability of acquiring ice information is important for planning and conducting offshore exploration and operations activities. In addition ice data is also important for developing and testing ice forecasting models.

The current generation of Landsat and weather satellites can provide ice data but only when cloud cover is not present. Landsat resolution is limited to 80 m and weather satellite resolution is at least an order of magnitude lower. In contrast, microwave sensors have an all-weather capability. Imaging radars such as the synthetic aperture radar (SAR) on Seasat can achieve on image resolutions of 25 m for mapping ice types and measuring ice characteristics in some detail. Aircraft imaging radars can achieve similar resolutions. The real aperture SLAR used in this experiment has a range resolution of 30 meters and an azimuth resolution varying from 24 meters at 03 km range to 290 meters at 35 km range. The Nimbus-7 scanning multichannel microwave radiometer (SMMR), essentially identical to the Seasat SMMR, can be used to measure ice extent, type (first year or multiyear), and temperature at course resolution.

It should be noted that the present project is complemented by two other AOGA activities relating to ice in the Bering Sea. In one, Oceanographic Services Inc. (OSI) has carried out detailed aerial stereo photography and ice reconnaissance in the Bering Sea during 1977 and 1978. This project is planned to continue in 1979 and the OSI data flights made simultaneously with the planned imaging radar flights will provide truth data for the present project. In the



other project, Environmental Research and Technology Inc. (ERT) has performed detailed analysis of Bering Sea Landsat imagery for the years 1973-77. The ice information and techniques developed for ice image interpretation may be of value in interpreting imaging radar and SMMR data.

#### Objectives/Purpose

The experiment objective is to evaluate the capability of microwave remote sensors to measure sea ice characteristics and extent and to assess the application of such sensors to future industrial operation of such sensors to future industrial operations in the Bering Sea. Microwave sensors to be evaluated are:

- (1) aircraft real aperture imaging radar - (AN/APS-94D Side Looking Airborne Radar) and
- (2) Nimbus-7 Scanning Multiband Microwave Radiometer (SMMR).

#### Approach

The experiment is planned to occur during March 1979 while significant ice cover exists in the Bering Sea. The imaging radar data will be acquired by NASA. NASA Lewis Research Center's C-131 aircraft with an AN/APS-94 D side looking airborne radar (SLAR) will fly on 3 days covering two strips approximately 500 km long each day. The width of each strip will vary between 70 and 100 km. Figure 1 indicates the flight lines of greatest interest and Table I describes the SLAR characteristics. Aerial photography (RC-8 cameras) will be taken concurrently with all SLAR flight lines.

The NASA Environmental Data Center at Goddard Space Flight Center will also provide Nimbus-7 SMMR data for the areas imaged by the radar. It should be noted that for power budgeting considerations, the SMMR is operated 50% of the time and will only take data on alternate days. Table II summarizes some of the SMMR characteristics.

Truth data consisting of low altitude aircraft photograph will be collected by Oceanographic Services Inc. (OSI) for AOGA. Surface measurements of ice properties made by OSI may be made available. The OSI flights will be coordinated with the NASA SLAR flights. Satellite imagery from Landsat and Tiros will be obtained if sufficiently cloud-free images are available.

Table III summarizes the ice parameters to be extracted from the microwave data. Category I includes those parameters which can be determined from aircraft SLAR and Nimbus-7 SMMR. Category II lists the parameters which could be expected to be extracted from SLAR only. Basically, OSI will conduct all analysis and assessment of data products to determine the capability of microwave sensors to measure ice properties of interest. NASA will be responsible for providing the microwave data products, specifically the ice concentration and boundary maps from the SMMR data as well as the SLAR images. Additionally, SLAR digital data of selected sites will be made available if requested by OSI.

NASA LeRC will also provide imagery of aircraft X-band real aperture SLAR and aircraft X and L-band synthetic aperture radar (SAR) data collected in the Beaufort Sea. These data sets will provide the experimenters with some basis for possibly commenting on the utility of satellite SAR data which (1) would have been available from Seasat had not early mission failure occurred and (2) could become available from future satellite systems.

#### Reporting and Schedule

Progress Reports: NASA LeRC, as coordinator of this experiment, will submit periodic project progress/status reports to NASA HQ starting in June 1979. It is expected that the user will provide input for these progress reports, but this is not a formal requirement. NASA LeRC will provide the user with copies of all such reports.

Final Report: A final report (one camera-ready copy and fifteen (15) bound copies) will be prepared by the user upon completion of the experiment, but not later than Feb. 28, 1980. It is suggested that the report be prepared for general dissemination in accordance with good reporting practice. In accordance with the objectives of this project, the final report should specifically include the user's assessment as to:

- (1) the capability of aircraft imaging radar and the Nimbus-G SMMR to measure ice properties of importance for projected resource extraction activities in the Bering Sea and
- (2) the desirable characteristics of an operational ice information system that would be required for resource extraction activities in the Bering Sea.

#### Schedule

A planning schedule is shown in figure 2.

TABLE I

SIDE-LOOKING AIRBORNE RADAR CHARACTERISTICS

- MOTOROLA AN/APS-94D - REAL APERTURE
- R.F. POWER SOURCE: MAGNETRON
- OUTPUT POWER: 45 KWATT PEAK
- FREQUENCY: X-BAND, TUNABLE - 9:10-9.40 GHz
- PULSE WIDTH: 200 NSEC.
- PULSE REPETITION FREQUENCY: 750 PER SEC, OR RANDOMLY VARIABLE
- POLARIZATION: H-H
- ANTENNA LENGTH: 5.5M
- 3DB ANTENNA BEAM WIDTH:  $0.45\text{DEG} = 7.85\text{ MRAD}$
- RANGE RESOLUTION: 30M
- MINIMUM DETECTABLE SIGNAL: -97 DBM
- MAPPING SWATHS: 25, 50, 100 KM WITH OFFSET IN 10 KM STEPS,  
BOTH SIDES OF AIRCRAFT
- DIGITAL DATA PROCESSING: RETURNS FROM TRANSMITTED PULSES ARE DIVIDED INTO (1) 400 EQUAL RIGHT ANTENNA AND 400 EQUAL LEFT ANTENNA GROUND RANGE BINS OR (2) 3200 EQUAL RIGHT ANTENNA AND 3200 EQUAL LEFT ANTENNA GROUND RANGE BINS. FOR EACH RANGE BIN, THE SLAR VIDEO SIGNAL IS SAMPLED AND DIGITIZED INTO A SIX-BIT DATA WORD. THE DIGITIZED SLAR VIDEO DATA FROM A SINGLE RADAR PULSE ARE ACCUMULATED IN MEMORY AND AVERAGED EXPONENTIALLY WITH THE RETURN FROM THE PREVIOUS PULSES. AUXILIARY DATA INCLUDING AIRCRAFT DRIFT, GROUND SPEED AND LOCATION ARE MULTI-PLEXED WITH THE AVERAGED RADAR VIDEO DATA. OUTPUT IS A SERIAL Bi- $\phi$ -L DATA STREAM.
- IMAGE OUTPUTS: -REAL TIME FULL RESOLUTION ANALOG WET PROCESSED FILM  
-REAL TIME DIGITALLY DRY SILVER PROCESS PAPER OR FILM  
-COMPUTER PROCESSED  
FALSE COLOR IMAGE GIVING REFLECTED SIGNAL POWER AND  
ESTIMATED RADAR CROSS SECTION
- DIGITAL TAPE OUTPUT -----

TABLE II

## NIMBUS-7 SCANNING MULTIBAND MICROWAVE RADIOMETER (SMMR)

- 5 CHANNELS	$\lambda$ (CM)	$f$ (GHZ)
	4.54	6.6
	2.8	10.7
	1.66	18.0
	1.36	21.0
	0.81	37.0

- 730 KM GROUND SWATH CENTERED ON SATELLITE SUBTRACK
- RESOLUTION ~25 - 150 KM DEP ON CHANNEL
- ALGORITHMS BEING APPLIED INCLUDE:
  - SEA ICE CONCENTRATION: SPATIAL RESOLUTION - 25 KM  
ACCURACY = 5%
  - MULTIYEAR ICE FRACTION: SPATIAL RESOLUTION - 150 KM  
ACCURACY = 20%
  - SEA ICE SURFACE TEMPERATURE: SPATIAL RESOLUTION - 150 KM  
ACCURACY = 4K



TABLE III ICE PARAMETERS TO BE DETERMINED FROM  
MICROWAVE DATA (BERING SEA)

CATEGORY	ICE PARAMETER	REMOTE SENSING NW DATA SOURCE	TRUTH DATA	PARAMETER EXTRACTION METHOD/RESPONSIBILITY
I	A. PERCENT ICE IN OPEN WATER	A/C SLAR, NIMBUS-7 SMMR	A/C PHOTOGRAPHY, LANDSAT IMAGERY	- PREDICTION OF ICE CONCENTRATION AND BOUNDARY FOR SMMR DATA PROVIDED BY NASA
	B. ICE BOUNDARY	"	"	- OSI WILL ANALYZE IMAGING RADAR DATA USING SLAR DATA PRODUCTS PROVIDED BY NASA
II	A. FLOE SIZE & DISTRIBUTION	A/C SLAR	SURFACE TRUTH, A/C PHOTOGRAPHY AND LANDSAT IMAGERY	- AOGA WILL CONDUCT ALL ANALYSES
	B. LEAD SIZE & DIRECTION	"	"	- NASA WILL PROVIDE: (1) SLAR IMAGE PHOTO PRODUCTS OF SELECTED SITES
	C. PRESSURE RIDGE SPA, FREQ. & ORIENT.	"	"	(2) SLAR DIGITAL DATA OF SELECTED SITES AS REQUESTED BY OSI
	D. FAST ICE	"	"	
	E. DETECTION OF LARGE GROUNDED ICE FEATURES (FLOEBERGS)	"	"	
	F. RUBBLE PILES	"	"	
	G. DIFFERENTIATION BETWEEN THIN, YOUNG & FIRST YEAR THICK ICE	"	"	

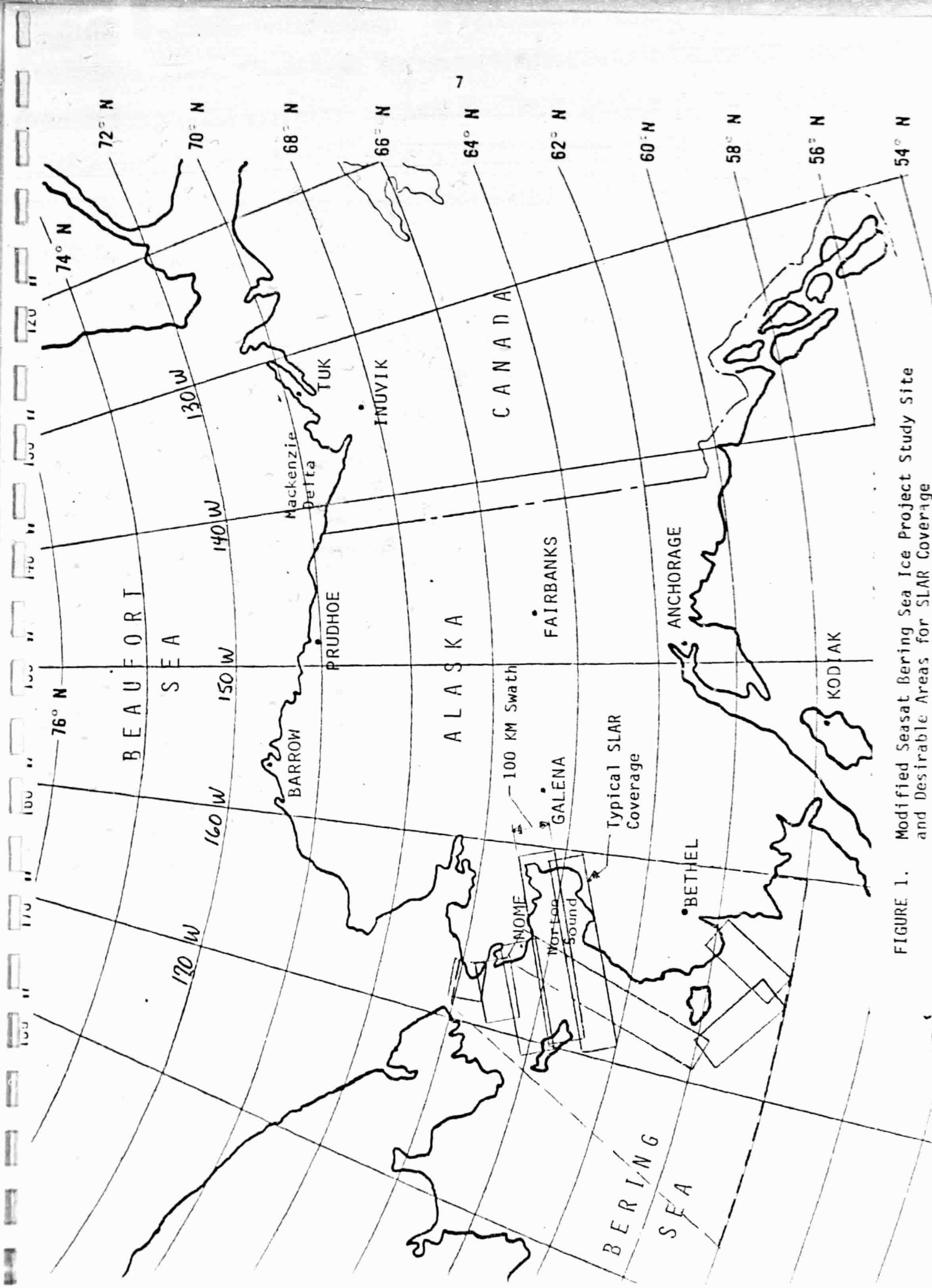
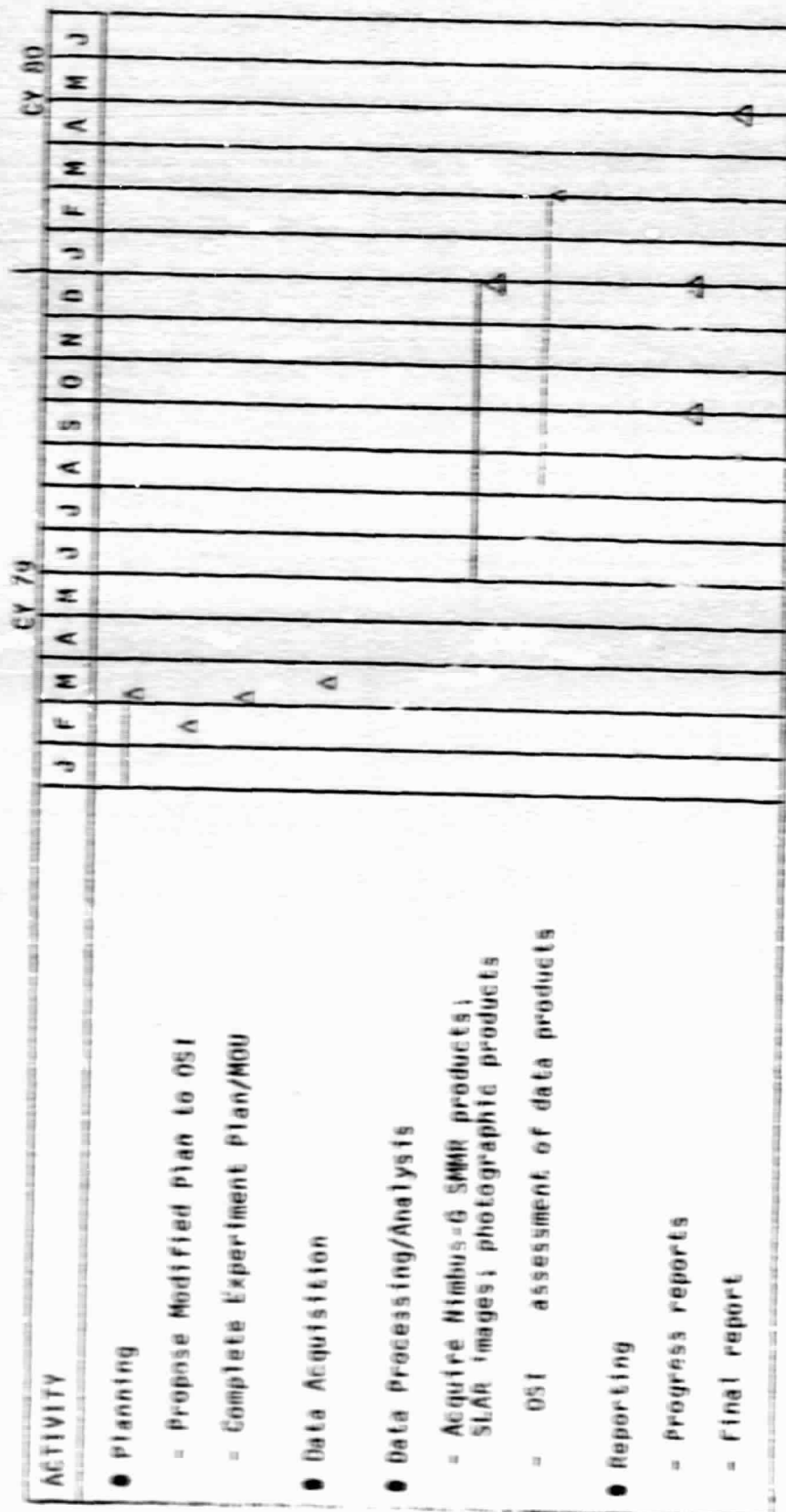


FIGURE 1. Modified Seasat Bering Sea Ice Project Study Site and Desirable Areas for SLAR Coverage





NORTH SEA OIL AND GAS

(ASVT EXPERIMENT 8)

NASA/UNION OIL COMPANY AND CONTINENTAL OIL COMPANY  
COOPERATIVE EXPERIMENT PLAN

July 1978

AMENDMENT 1

MARCH 1979

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
Office of Space and Terrestrial Applications  
Washington, D. C. 20546

## EXPERIMENT SUMMARY

ASVT EXPERIMENT: No. 8

TITLE: North Sea Oil and Gas

EXPERIMENT REPRESENTATIVE/ORGANIZATION: (Mike Utt) Union Oil Research, P.O. Box 76, Brea, CA 92621. Telephone: (714) 528-7201; and (Ronald Gratz) CONOCO, R&D Dept., Ponca City, OK 74601. Telephone: (405) 762-3456, Ext. 4477.

COORDINATOR: (A. George Mourad) Battelle's Columbus Laboratories, 505 King Avenue, Columbus, OH 43201. Telephone: (614) 424-5097.

EXPERIMENT LOCATION: The test area of primary interest is bounded by 56°N-62°N and 4°W-4°E, which includes mainly United Kingdom and Norwegian areas of the North Sea.

OBJECTIVE/PURPOSE: To determine the feasibility of using Seasat data for improving on design of structures and to assess data utility for daily operations.

APPROACH: The Seasat data to be provided by NASA will be processed and compared with surface truth data obtained from CONOCO/UKOOA and Union Oil stations and platforms. These platforms are instrumented in a standard fashion and will be used for verification of Seasat data. Based on the results of comparison, the data will be assessed in terms of their utility for platform design, as a substitute for surface instrumentation, and for improvement of short-term weather forecasting for offshore operations.

DATA REQUIREMENTS: Only non-real-time data are required. These include GDR data on magnetic tapes readable on an IBM 370/158 system.

COMMUNICATIONS EQUIPMENT AND DATA DELIVERY: Union Oil will receive data by mail in Brea, California, and CONOCO will receive data by mail in Ponca City, Oklahoma.

SURFACE TRUTH DATA: Data being collected from platforms include wind, waves, temperature, and barometric pressure.



### North Sea Oil and Gas Experiment

This experiment is being conducted by the Continental Oil Company (CONOCO) and Union Oil Company in cooperation with NASA for the purpose of evaluating the potential that Seasat data have for affecting the decision processes that must be made in the design of offshore structures and during offshore oil and gas exploration and production.

The North Sea is one of the major oil and gas producing areas of the world. There is a need for the oil companies to collect environmental data to aid in the design of new structures and for daily operations. The area of primary interest is bounded by 56°N-62°N latitude and 4°W-4°E longitude, which includes mainly United Kingdom and Norwegian areas of the North Sea. Union Oil interest in this area includes, in particular, the Heather oil field located at 60°57'N, 0°5'E, in the UK area of the northern North Sea. CONOCO's area of interest includes four sites/stations operated by the United Kingdom Oceanographic Operators Association (UKOOA). These stations are:

Brent platform at 61°04'N and 01°43'E

Forties platform at 57°44'58"N and 00°54'55"E

Foula buoy at 60°07'30"N and 02°57'00"W

Frigg platform at 59°52'32"N and 02°03'42"E

Figure 1 shows the location of these UKOOA stations and the Heather oil field.

The oil companies currently have environmental data taken from the four platform stations in the test area that will be used to determine the applicability and benefit of Seasat data for establishing design and operational criteria for offshore operations.

### Summary of the Physical Environment

The North Sea is characteristically a region of very severe storms, particularly in the northern latitudes. Water depths are generally between 40 and 200 meters, except in the Norwegian Trench, along the coast of Norway, where depths exceed 400 meters. Severe storms in the North Sea can come from any direction, and at any season of the year. In the

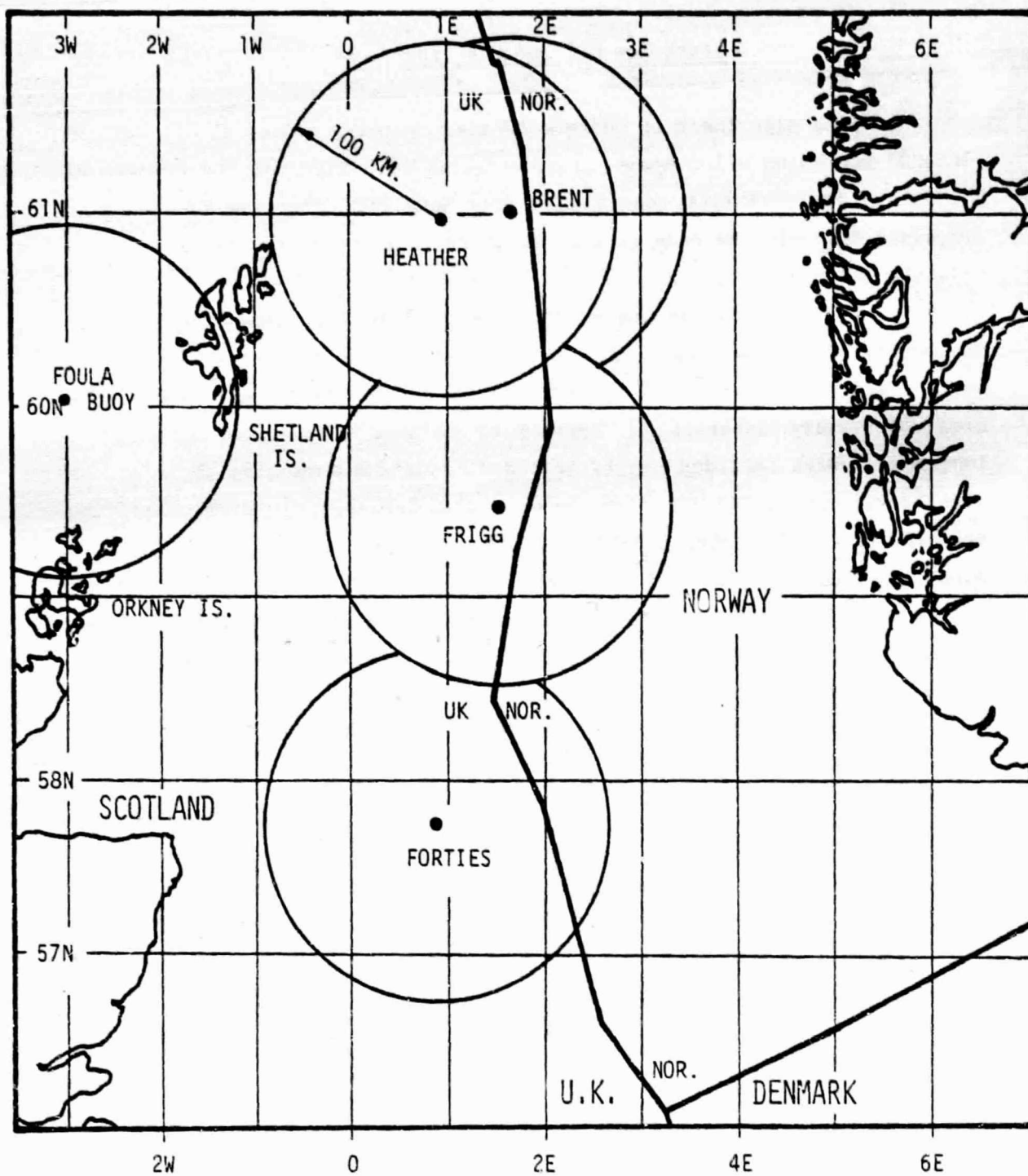


FIGURE 1. LOCATION OF OFFSHORE PLATFORMS IN NORTH SEA TEST AREA

northern North Sea, design wave heights up to 31 m have been used. Extreme wave heights are not as high in the more sheltered southern portions of the area of interest.

#### Experiment Motivation

The North Sea as a test bed is one of the best oil and gas development fields we have today. The field is not yet fully developed and there are many structural design and operational criteria that will be based on future data. The oil companies are looking for more data, both environmental and structural, that will enable them to design offshore structures more safely. If Seasat data were verified and an ocean-monitoring satellite commenced normal operation, significant economic benefits could be realized. Additionally, the oil companies would be able to reduce the use of weather ships and rig environmental data collection.

#### Objectives/Purpose

The objectives of the North Sea experiment are to determine the feasibility of using Seasat data to improve the design of offshore structures and, if the data prove to be of sufficient accuracy, to assess their utility for developing methods of incorporating similar future satellite data into daily operations.

#### Approach

The Seasat satellite failed on 10 October 1978, having yielded about 3 months of data which will be provided to CONOCO and Union Oil in non-real time in the form of Geophysical Data Records (GDRs). The GDRs will be used in satellite data evaluation case studies to validate sensor capability and determine the forecasting value of the sensor data.

CONOCO and Union Oil companies will obtain surface truth data from the four UKOOA buoy/platform stations (UKOOA has agreed to supply data to this experiment). Both companies will compare the Seasat data with the surface truth data collected within a 100-km radius of the platforms. Interpolation and extrapolation of the Seasat data will be made with the



point values measured by the platforms. If the comparisons indicate the validity of the Seasat data, the data will be assessed in terms of their utility for platform design, as a substitute for surface instrumentation, and for improvement of short-term weather forecasting for offshore operations.

Specifically, CONOCO will compare the Seasat data with the environmental data they have collected in order to determine how they can utilize the data available from future satellite programs; their main interest is in a system that will show high waves. The purposes of their case study are: (1) to establish how weather forecasting can be improved, and (2) to collect data on severe weather conditions and establish a data base for long-term purposes.

Similarly, Union Oil's case study will consist of analysis and validation of non-real-time data. First, the Seasat data available on waves, wind and sea surface temperature will be analyzed; then, these data will be compared with weather conditions known to exist at that time. A forecast analysis will be made to determine what could have happened had GDR data been available at that time. Finally, under the validation task of this case study, the Seasat data will be compared with the collected surface truth data, and an evaluation made as to the utility of the Seasat data for severe weather forecasting. A report will be issued summarizing statistical comparisons of Seasat and surface truth data and their applications to various offshore operations.

Industry Data Requirements. NASA will provide both Union Oil Company and CONOCO with a set of the Seasat Geophysical Data Records (GDR). These records include the altimeter ( $H_1/3$ ), scanning multifrequency microwave radiometer (SMMR) wind magnitude, Seasat-A scatterometer system (SASS) wind magnitude and direction, and SMMR sea surface temperature.

The minimum accuracy\* required by both companies for the altimeter data is 20 percent of the measured value. For the SASS data, the minimum accuracy required is  $\pm 5$  m/sec (or 30 percent of the measured

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\*Both Union Oil and CONOCO would like to receive a complete set of Seasat data with the final improved accuracies achievable from these sensors.

value) for wind magnitude and  $+40^\circ$  for wind direction. Their SMMR minimum accuracy requirements for sea surface temperature data are  $\pm 1^\circ\text{C}$  relative and  $\pm 4^\circ\text{C}$  absolute. In all cases, the time period of interest is from 1 July to 10 October 1978. The priority in which the data are required is: (1) waves, (2) wind, and (3) temperature.

Surface Truth Data. CONOCO and Union Oil currently have available environmental data measured on four UKOOA platform/buoy stations between 1 July and 10 October 1978. Table 1 shows the surface truth data acquisition locations, types and frequency of measurements. Further details for the Brent B platform and the Foula buoy are presented in Tables 2 and 3, respectively. Data from the remaining two platforms will also be included once they become available. These surface truth data will be used in a comparative analysis with Seasat and related data.

#### Data Format and Communication Equipment

The Seasat data products should be written on a magnetic tape which is readily readable on an IBM 370/158 system. One set of tapes will be mailed whenever data become available to both CONOCO and Union Oil Company at their respective locations in Ponca City, Oklahoma, and Brea, California.

#### Reporting and Schedule

Guidelines for reporting the experiment results are given in the paragraphs that follow.

Progress Reports. Battelle will submit periodic progress/status reports to NASA HQ. It is expected that the experimenter will provide inputs for these progress reports, but this is not a formal requirement. Battelle will provide the experimenter with copies of all such reports submitted to NASA.

TABLE 1. SURFACE TRUTH DATA AVAILABLE BETWEEN  
1 JULY AND 10 OCTOBER 1978

Station	Longitude/ Latitude	Frequency of Reports	Time Lag Between Acquisition of Data and Reports	Accessibility of Raw Data	Products				
					Significant Wave Height	Wind Speed and Direction	Water Temperature	Tidal Informa- tion	Other Products
Brent (UK00A)	61°04'N 01°43'E	Quarterly	6 months	Immediate if requested	~20-min observation every 3 hr	~10-min mean every hour	30-sec mean every hour	None	Barometric pressure, air temperature
Forties (UK00A)	57°44'58"N 00°54'55"E	Not known	-ditto-	-ditto-	20-min observation every 3 hr	10-min mean every hour	0.5 min of observation every hour	-ditto-	None
Foula (UK00A)	60°07'30"N 02°57'00"W	Quarterly (data analyzed monthly)	-	Monthly	20-min observation every hour	-ditto-	-ditto-	-	Barometric pressure, air temperature
Frigg (UK00A)	59°52'32"N 02°03'42"E	Not known	Not known	Immediate if requested	-ditto-	-	-	-	None

TABLE 2. SURFACE TRUTH DATA TAKEN FROM THE BRENT B PLATFORM  
(61°04'N LATITUDE, 01°43'E LONGITUDE) BETWEEN  
1 JULY AND 10 OCTOBER 1978

Parameter/Observation*	Instrumentation (Barom, Anemom, Thermom, Visual Obs)	Frequency of Observation
Wave Height	Datawell waverider and Baylor wave staff	Continuous, 17.07 min every 3 hr
Sea Surface Temperature	E906 Rosemount platinum resistance thermometer at 5 m below surface	Continuous, 0.5 min every hour
Wind Speed and and Direction**	R.W. Munro, Type 1M 146 modified BS4683, part 3, 1972 Ex-N taken at 55-m height	Continuous, 8.53 min/hr
Air Temperature	E906 Rosemount platinum resistance dry bulb thermometer	Continuous, 0.5 min every hour
Barometric Pressure	KDG ACT 20 B transmit- ting aneroid	-ditto-

\*There is a time lag of up to 6 months for receipt of recorded data.

\*\*Height correction for 10 m above sea level using 55 m - 1/1.232.

TABLE 3. SURFACE TRUTH DATA TAKEN FROM THE FOULA BUOY  
(60°08'N LATITUDE, 02°57'W LONGITUDE)  
BETWEEN 1 JULY AND 10 OCTOBER 1978

Parameter/Observation*	Instrumentation (Barom, Anemom, Thermom, Visual Obs)	Frequency of Observation
Wave Height	Datawell heave sensor mounted at center of buoy	Continuous, 17.07 min/1 hr, 2048 samples (rate = 2 Hz)
Sea Surface Temperature	Rosemount Model E13418 Mod. 0 platinum re- sistance thermometer 0.4 m below water line; Rosemount trans- mitter model E32025	0.5 sec/hr, average of 64 values
Wind Speed	Brooks and Gatehouse Type D8102 (modified counting) cup ane- mometer 6.7 m above sea level	Total count, 10 min/hr
Wind Direction Relative to Buoy	Brooks and Gatehouse Type D7250 (Vane) 6.7 m above sea level	300 values, 10 min/hr (rate 0.5 Hz)
Buoy Orientation	Brooks and Gatehouse "Halcyon" flux gate magnetic compass 3.66 m above sea level	
Air Pressure	KDG Series 8190 inte- grated aneroid baro- meter with static pressure head mounted at sea level	10 min/hr, 300 values (rate = 0.5 Hz)
Air Temperature	Rosemount Model E13418 Mod. 0 platinum re- sistance thermometer in screen 3.05 m above sea level	0.5 sec/hr, average of 64 values

\*There is a time lag up to 6 months from observation time to receipt of data.



Final Report. A final report (one camera-ready copy and four bound copies) will be prepared by the experimenter upon completion of the experiment, but not later than December 31, 1980. It is suggested that this report be prepared for general dissemination in accordance with good reporting practice. It may include experiment objectives, experiment description, techniques and procedures employed for the data analysis and assessment, conclusions and recommendations. Also desirable is the experimenter's assessment of the results in terms of:

- (1) Potential contribution of Seasat data to the experimenter's future needs
- (2) Characteristics of an operational satellite system that are of importance to the users.

Schedule. A planning schedule for this experiment in the North Sea is shown in Figure 2.



APPENDIX

TWO TASK PUBLICATIONS



## Applications of Seasat to the Offshore Oil, Gas, and Mining Industries

A.G. Mourad\* and A.C. Robinson†  
*Battelle's Columbus Laboratories, Columbus, Ohio*

Seasat-1, a NASA satellite launched in June 1978, was designed to provide synoptic, repetitive data on the ocean areas of the world. Seasat-1 carries five sensors, four with all-weather capability. The principal data products will be surface wind speed and direction, wave height, and sea surface temperature. Other information provided will include wave length, wave direction, ice characteristics, and ice movement. One of NASA's objectives is to demonstrate Seasat capability and to permit evaluation of the practical value of the data to offshore industry users. Thus, this paper describes several industrial experiments planned by NASA during the operation of Seasat-1. These experiments are to be conducted with several industries, including oil, gas and mining organizations which will be investigating the usefulness of the data. Applications include 1) improvements in weather and wave forecasts, 2) improved knowledge of past wind and wave statistics for setting design requirements, and 3) monitoring ice formations, breakup, and movement in arctic regions. A number of geographical areas are being examined, including the Beaufort Sea, Labrador Sea, Gulf of Mexico, U.S. East Coast, West Africa, Equatorial East Pacific, Bering Sea, and the North Sea. These investigations are being done jointly by NASA and the participating industrial organizations. NASA will provide the appropriate Seasat-derived data, and the industrial organizations will compare these data with their own observations and estimate the usefulness to offshore operations. Results will be available to the entire offshore industry and to the general public once the evaluations are completed.

### Introduction

IN June 1978, NASA launched Seasat-1, the first satellite dedicated primarily to measurement of the characteristics of the ocean surface. It is also the first satellite to make extensive use of microwave sensors. With the exception of the synthetic aperture radar (SAR), the sensors provide global coverage (excluding the extreme polar regions) on a 36-h repetitive cycle. With these instruments, Seasat can provide global coverage of such parameters as 1) significant wave height, 2) ocean currents, 3) surface wind speed and direction, and 4) sea surface temperature. In addition, the SAR can provide information (over restricted areas) on ice characteristics and movement and on wave length and direction. Because of orbit characteristics, SAR coverage will be most effective in high latitudes. It can, however, be used on other ocean regions and for observation of land areas as well. It also may be possible to detect internal waves and to develop a better understanding of ocean circulation. Thus, Seasat will cover many natural phenomena of importance in offshore oil, gas, and mining operations.

Preliminary estimates of Seasat benefits were made during 1974-1975.<sup>1</sup> In the case of offshore oil and gas, these showed that benefits during the years 1985 to 2000 would range from \$214 to \$344 million (1975 dollars). In addition, \$96 to \$288 million should accrue to arctic operations, most of which are associated with the oil and gas industries. No estimates were made in that study for the deep ocean mining industry, but the benefits should be substantial.

In economic terms, these industries are highly significant. The offshore oil and gas industry represents the largest single economic activity in the world's oceans.<sup>2</sup> The value to the U.S. alone was estimated at \$3.2 billion in 1973, with projections

of \$18.9 billion by the year 2000. Ocean mining activities are projected to reach \$2.5 billion by the year 2000; the U.S. mining industry alone will have spent some \$300 million before the first commercial operations begin.<sup>3</sup>

Throughout the Seasat program, NASA has devoted substantial effort to getting potential users involved. From the early conceptual phases to the present, there has been in existence a users' committee, consisting of representatives from government, the academic community, and industry. This committee has been a major influence in bringing the Seasat program to its present configuration.

Although Seasat-1 is a "proof-of-concept" satellite, NASA included as one of its goals the actual demonstration of the utility of Seasat data to operational users. To accomplish this, NASA is setting up experimental programs with selected potential user industries. Thus, NASA is exposing satellite performance to the outside user prior to full verification of capability. However, this early evaluation by users can contribute to the verification and to a better understanding of the requirements of an operational system. Through these demonstrations, NASA plans to transfer its technology directly to the user, who, in turn, is expected to provide evaluation of Seasat capability and its impact on its operations.

In addition to the offshore industry demonstrations, which are the subject of this paper, there are a number of other similar activities that will be undertaken in the same period. These include activities in the areas of marine resources, marine transportation, fisheries, and other biotic resources. If the experimental results justify it, an operational Seasat may be orbited in the early to mid-1980's.<sup>4</sup> This operational system probably will have multiple satellites, as well as improvements in sensors and data-handling capability. This paper covers the offshore oil, gas, and mining industries' experimental plan for verification of Seasat benefits to these industries and provides some description of Seasat capabilities as they apply to the industries' requirements.

### Objectives of the Offshore Industry Verification Experiments

These experiments are designed to 1) assist in verification of the capabilities of the Seasat-A sensors, 2) permit potential

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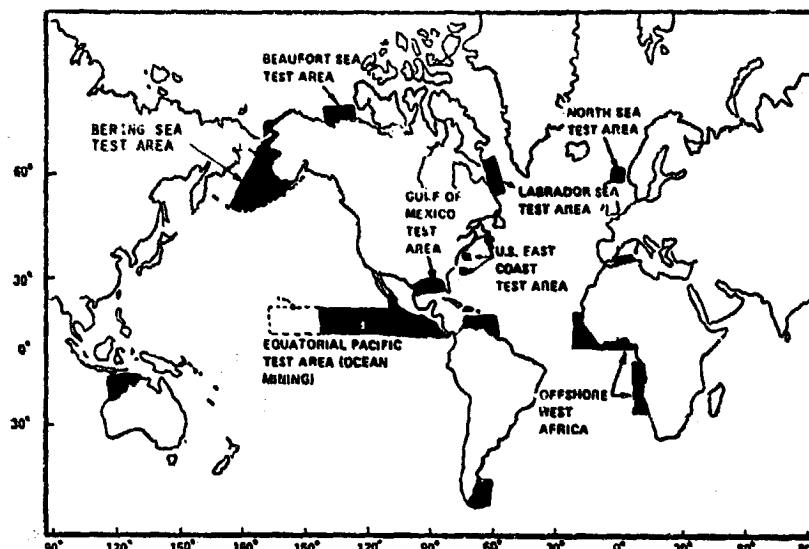


Fig. 1 Approximate locations of offshore oil, gas, and mining industries test areas for the Seasat-1 verification experiment.

users to evaluate the practical value of the data in their activities, 3) begin the process of transferring the technology to the user community, and 4) assist in developing the requirements for an operational system for monitoring the oceans from space.

### Experiments and Participants

Table 1 summarizes the verification experiments, showing the industry organizations that are participating and their geographical areas of interest. Figure 1 shows the approximate location of the proposed test areas.

### Description of Seasat-1

The total system to be used in the experiments consists of a number of components, from the instruments on the spacecraft to the mechanisms for delivering data at the user's facility. These system components are described briefly below. For more complete details, see Nagler and McCandless,<sup>4</sup> NASA's system description,<sup>5,6</sup> and Apel and Siry.<sup>7</sup>

#### Instruments

##### Radar Altimeter

The altimeter has two functions. First, it monitors the average wave height from 1 to 20 m along a narrow swath directly below the satellite path. Second, by measuring changes in the satellite-to-sea-surface distance, it can detect variations in mean sea level (geoid), tides, storm surges, and currents. This is an improved version of the altimeters flown on Skylab and GEOS-3.

##### Radar Scatterometer

The scatterometer acts as an anemometer for measurement of surface wind speeds and wind direction. The instrument covers two 500-km swaths, one on each side of the nadir. The Seasat-1 scatterometer is an improved version of the Skylab instrument. Global coverage (95%) is possible every 36 h.

##### Microwave Radiometer

The scanning multichannel microwave radiometer (SMMR) is a passive system that measures the emitted electromagnetic radiation in selected regions of the spectrum. It has five separate frequency bands and performs four functions: 1) measurement of the surface temperature, 2) measurement of foam brightness, which can be converted into a measurement of wind speeds, 3) detection of ice age, extent, concentration, and dynamics, and 4) atmospheric corrections for the radar altimeter and scatterometer. Similar instruments were flown

on Skylab, Nimbus 5, and Nimbus 6. Global coverage (95%) will be obtained every 36 h.

##### Visible and Infrared Radiometer

The V/IR provides clear-weather surface temperature data, cloud coverage patterns, and corroborative images of ocean and coastal features. The instrument is a modified version of those flown on the National Oceanic and Atmospheric Administration (NOAA) operational satellites.

##### Synthetic Aperture Radar

The SAR is an instrument that has not flown previously in a satellite. It provides imagery of ocean features such as ice fields, icebergs and leads, slicks, wave and current patterns, and coastal conditions. The SAR is capable of penetrating clouds and nominal rain.

##### Data System

Data from all of the instruments except the SAR will be recorded onboard the satellite as the measurements are made. These data then will be transmitted to the ground when the satellite passes over one of the Seasat ground stations. The data then will be retransmitted to two locations: 1) NASA Goddard Space Flight Center (GSFC) and 2) the Navy's Fleet Numerical Weather Central (FNWC) at Monterey, Calif. At GSFC, the data will be combined with precise orbit information (obtained some days after the data are taken) and sent to the Jet Propulsion Laboratory (JPL) at Pasadena, Calif. There, the data will be archived to provide the major permanent repository of Seasat data. Some of the data from this file will be available to the public through the NOAA Environmental Data Service.

The use of the data at FNWC is rather different. The raw sensor outputs first will be converted to geophysical units (wind magnitudes, temperatures, etc.), and then the geophysical data will be used, along with conventional data sources, in preparation of FNWC's standard analysis and forecast products. Both the Seasat-1 data themselves and the analysis and forecast products based on the Seasat data will be sent over telephone lines to participants in the verification experiment program. In this near-real-time data system, data should become available to users within something like 6 h after the data are taken.

The SAR data will follow a different course. Because of the very high data rate produced by the SAR ( $10^6$  bits/s), it is not practical to store the data on board, and so the data will be transmitted to the ground as they are being taken. This means that the SAR can be used only while the satellite is in view of a

Table 1 Summary of offshore industry Seasat verification experiments

Test area/no. of companies <sup>a</sup>	Objectives	Data requirements	Applicable Seasat-A instruments <sup>b</sup>	Industry surface truth parameters
Beaufort Sea 125°-140°W offshore to 72°N APOA: 3 companies AOGA/ARC: Several	Improve meteorological forecasts Improve wave forecasts Monitor ice dynamics Ice forecast	Ice regime, breakup, growth and dynamics Wind Waves	V/IR, SMMR, Alt., SAR, (IR) Scat., SMMR (Alt., SAR) Alt. (SAR)	Ice condition Meteorology Wind Wave spectra (height, period, direc.)
Labrador Sea 150 miles offshore W 45°-65°N EPOA: 2 companies	Improve wind wave forecast Improve freezeup & breakup forecast Locate icebergs Provide historical data for design	Sea ice Icebergs Sea state  Current speed Current position	SAR, Alt., SMMR SAR Alt., SAR (Scat., SMMR, Vis.) Alt. (SAR, Scat.) IR, SMMR, Alt., SAR	Waves, (height, period and direction) Wind speed/direction Iceberg size, position Sea ice type, leads, roughness ridges Iceberg (in pack ice)
Gulf of Mexico Primary: 88°-96°W 27°-30°N Secondary: 80°-97.5°W 26°-30°N AGA/PRC: 25 companies	Improve design criteria for pipelines Validate sensor data Correlate surface data with subsurface data	Wind Waves and swells  Current  Surface temperature Water vapor Tides Extra tropical/tropical storms	Scat., SMMR (Alt., SAR) Alt., SAR (Scat., SMMR, Vis.) Alt., IR, SMMR, SAR (Scat.) IR, SMMR (Scat., Alt.) SMMR Alt. Alt., SAR, Scat., V/IR, SMMR	Wave Spectra Wind speed/direction Water temperature Air temperature Water vapor
Getty Oil, Texaco	Improve accuracy of prediction of severe storms			
U.S. East Coast 70°-75°W 38°-43°N CONOCO: operator for several companies	Improve wind-wave forecast (real time data) Provide historical ocean/meteor. data to determine applicability for operations and design criteria determination and model calibration	Waves Wind Surface currents  Tide Temperature Storm track	Alt. (SAR) Scat., SMMR (Alt., SAR) Alt., IR, SMMR, SAR (Scat.) Alt. IR, SMMR, Alt. (Scat.) Alt., SAR, Scat., V/IR, SMMR	Wave height/spectra Wind speed/direction Sea/air temperature Tide Current profile
Offshore West Africa 0°-12°N and 18°-35°S up to 2000-m contour W Getty: operator for several companies, and Texaco	Provide historical data for design Provide near real time wind, wave and current data	Waves Wind Current speed/direction Surface temperature	Alt. Scat., SMMR (Alt.) Alt., IR, SMMR V/IR, SMMR (Scat., Alt.)	Water temperature & salinity Waves (height, period, direction) Wind speed/direction Current speed/direction, temperature
Equatorial East Pacific Ocean Primary: 110°-150°W 5°-20°N Secondary: 110°-180°W 5°-20°N Ocean Mining: 4 consortia	Reliable prediction of sea and atmospheric conditions at 12, 24, 48 and 72 h	Storm genesis, location and path Wave/swell Wind Cloud cover Precipitation Temperature Currents	All instruments except SAR <sup>c</sup> Alt., SAR (Scat., SMMR) Scat., SMMR Vis. SMMR (Alt.) IR, SMMR (Scat., Alt.) Alt., IR, SMMR (Scat.)	Wave height/spectra Wind speed/direction Sea/air temperature Current
North Sea 56°-62°N 5°W-5°E CONOCO and Union Oil	Improve on design of structures Determine utility of data in operations	Waves Wind Temperature Storm	Alt. Scat., SMMR SMMR All	Wave height/spectra Wind speed/direction Sea/air temperature Tides & current
Bering Sea 54°-70°N 157°W to US/USSR border AOGA/Bering Sea Ice Task Force	Assess SAR imagery for assisting offshore operations in ice	Ice conditions type, distribution and dynamics	SAR and SMMR	Visual observations of ice and aerial photography

<sup>a</sup> Acronyms used include the following: APOA: Arctic Petroleum Operators Association; AOGA/ARC: Alaska Oil and Gas Association/Arctic Research Committee; EPOA: Eastcoast Petroleum Operators Association; AGA/PRC: American Gas Association/Pipeline Research Committee; CONOCO: Continental Oil Company.

<sup>b</sup> Parentheses denote secondary applications. Abbreviations used are as follows: V/IR visible and infrared radiometer; SMMR = scanning multifrequency microwave radiometer; Alt. = radar altimeter; SAR = synthetic aperture radar; Scat. = radar scatterometer; and Vis. = visible.

<sup>c</sup> SAR will not operate except in areas near U.S. and Canadian shores.

ground station equipped to receive the SAR data. At the ground station, the raw SAR are stored on tapes, which are sent to JPL for processing. At JPL, a portion of the data will be processed into images. These should be available within two to three weeks after the data are recorded.

#### Data Products

There will be many users of Seasat-1 data, and the range of products which will be prepared is correspondingly wide.

Some of the principal characteristics of the planned data products are suggested below.

#### Near-Real-Time Data

The products that will be prepared by and disseminated through FNWC are of two types: the Seasat-1 data themselves, and the derived analyses and forecasts. The Seasat-1 data will be sent out in tabular form, e.g., sea surface temperature, together with the geographical location and time at

which they were taken. The analysis and forecast products will be sent as maps showing lines of constant pressure, lines of constant temperature, wind directions, etc. Wave spectra will, however, be sent in tabular form.

#### *Non-Real-Time, Non-SAR Data*

The archive of non-SAR data at JPL will consist primarily of time- and position-tagged raw instrument outputs. Only selected portions will be converted to geophysical units. The raw data could be made available to users, however, as could any portions of the data which have been converted to geophysical units. In both cases, the data would be in digital form, stored on tapes.

#### *SAR Data*

SAR data will be collected only on a limited basis. The SAR will make some 1500 passes/y, although only 260 of these passes are scheduled for reduction to images. Each pass will consist of 10 min of observation, representing a ground track coverage of  $100 \times 4000$  km. The images can be made available in digital form on tape, as prints, as positive transparencies, or as negatives.

### **Applications of Seasat-1 Data**

Seasat-1 will be providing types and amounts of data, most of which never before have been available. It is expected that offshore industry users will develop uses for the data which cannot be foreseen now, but a number of uses have been identified in preliminary planning and will be tested during the experiment period. Two major types of applications are planned: 1) use of historical data for designing offshore structures or for long-range operational planning, and 2) use of weather and wave forecasts to assist in making operational decisions. There is a third potential area that could develop later: use of Seasat data to assist in geophysical exploration.

In these types of applications, the new capabilities of Seasat are quite valuable. The global all-weather coverage permits collection of environmental information in those remote and/or inhospitable ocean areas that are of increasing interest as the search for oil, gas, and mineral resources widens. In some of these areas, human activity has been minimal, so that there is little information. In other cases, cloud cover is quite common, so that other satellite systems are not highly effective. Some of the specific data applications are suggested below.

#### **Waves and Wave Forecasting**

Historical wave data will be collected and stored for generating wave statistics. These will be useful for platform design, pipeline laying and design, and ocean mining operational planning.

Positioning of mobile rigs, installation of fixed structures, hole re-entry, salvage operations, and resupply are executed best when winds and waves are low. Prediction of hurricane-produced winds and surges is required to shut down operations when necessary. The primary parameters involved in wave forecasting include storm surge/setup, wave spectra, surface winds, and wind stress. Altimeter wave-height observations, along with the scatterometer and microwave radiometer data on winds, will be used to verify existing models or improve on the accuracy of wave forecasting. Several organizations, such as NOAA and FNWC, expect to have improved spectral wave forecasting models in operation by 1978. Their extension to a truly global scale will depend upon the establishment of satellite techniques for measuring surface winds.

#### **Winds**

Surface wind information generated from Seasat will provide a major new data source for meteorological forecasting. It is expected that this will be particularly

significant in certain regions in which limited weather data are available. On a historical basis, wind statistics will be significant in the design of offshore facilities such as fixed platforms, mobile rigs, mining ships, salvage equipment, and ocean dumping barges.

#### **Weather Forecasting**

The global coverage of surface wind and temperature will provide a major new resource for weather forecasting. Since the Seasat data are different from conventional data sources in spatial extent and in timing of the measurements, some adaptation in analysis and prediction models will be required. Ultimately, new and much more accurate models may be developed, but this is beyond the scope of the Seasat experiment program. FNWC will be adapting their analysis procedures to accept the synoptic Seasat data and distributing the resulting products to participants in the program. The impact of wind data on global 36- and 72-h forecasts will be assessed by FNWC, NOAA, and Canada's Atmospheric Environmental Services. Comparisons between forecasts and observations could be made available to experimenters in specific areas. Offshore industry experimenters will be comparing the Seasat-based forecasts with their own observations and experience.

#### **Hurricane Forecasting**

Seasat instruments, especially the scatterometer, the SAR, and the altimeter, should make possible better understanding and prediction of hurricanes. However, this will depend also on improved modeling, which may not be available during the experiment period but is promising for the longer term. The SMMR should give a rather rough picture of the wind field. The SAR can penetrate the hurricane and provide much more detailed information on waves, but complete, repetitive SAR coverage will not be possible with Seasat-1.

#### **Surface Temperature**

Measurement of surface temperature also will be useful in meteorological forecasting. In northern latitudes, information on air and water temperatures is needed to predict icing on structures.

#### **Sea Ice Mapping and Statistics**

Monitoring of iceberg location and movement is extremely important for drill rigs and shipping. Mapping of ice leads, floes, and movement is critical for ship navigation and extension of the operating season. SAR and microwave imagery will be used to update and improve the analysis of sea ice in the Beaufort, Bering, and Labrador Seas.

#### **Ice Dynamics**

Studies by the Surveillance Satellite Project Office of Canada's Department of Energy, Mines and Resources, along with those of NOAA,<sup>8</sup> will involve 1) determining the quantitative accuracy and detail with which sea ice can be mapped employing SAR and SMMR data, 2) assessing the capabilities of SAR and SMMR to collect the required all-weather temperature data for sea ice dynamics measurements, and 3) applying Seasat-1 capabilities to classification of ice types and distribution of features. Monitoring of ice dynamics during freezeup, including growth and progression of landfast ice and the southerly migration of the polar pack, is important in assessing the ice loading on fixed platforms.

### **Experiment Program**

As mentioned earlier, Seasat-1 was launched in June 1978. It is expected that the distribution of data to the offshore industry users will begin late in 1978, after a period allotted to validation of the instruments and the data system. The experiment period will last for approximately two years. As of this writing, all hardware and software required to support

the experiments is either complete or in late stages of preparation. Planning for the experiments is nearly completed, and NASA and the users are working out details of agreements on the responsibilities of the various parties. At the end of the experiment period, the offshore industry participants will provide NASA with a report covering the experimental activities and evaluating the Seasat data as to validity, as well as to significance in assisting offshore industrial activities.

It should be emphasized that there will be many activities using Seasat-1 data in addition to the offshore industry uses reviewed here. There will be a number of instrument validations, scientific investigations, and commercial applications such as in marine transportation and fisheries. In all of these activities, NASA is placing an unusual degree of reliance on other organizations to assess the data, whether that assessment is in technical, scientific, or practical terms.

### Conclusions

In recent years, several satellite systems have proved their usefulness in providing data on a global basis with speed and cost advantages over existing systems. Seasat-1 is the first satellite dedicated to ocean monitoring. If it is successful, it is expected that more advanced versions will follow, leading to an operational system in the mid-1980's.<sup>5</sup> Seasat-1 is the first step, then, to a major new capability for understanding, controlling, and using the ocean environment.

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## REQUIREMENTS FOR OFFSHORE FACILITIES DESIGN AND OPERATIONS

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As man seeks to solve the multiplying energy and environmental problems confronting him, he is turning more and more to the sea. The search for oil and gas in offshore areas on the continental shelves and slopes of the world oceans has increased considerably during the last two decades. Deep ocean mining is becoming increasingly attractive. The use of the seas for food and the development of ocean resources for transportation, recreation, and other activities, encourage the immediate development of this most important frontier.

Harnessing the hostile ocean environment to develop the resources and extract potential economic benefits will require many new and improved technologies. One of the most significant is the technology of information. This includes information on the ocean environment, navigation information and logistical information required for support of offshore operations. Design of facilities and structures requires historical environmental data for the region of interest. Operations often require both current real-time data and environmental prediction methods to enhance safety and economy. Satellite systems offer ways of obtaining and handling those types of information which may prove to be more effective and economical than traditional methods. This paper reviews those types of data in terms of their effect on the ocean activities: exploration, production/operations, transportation, and data collection.

### Exploration

Exploration includes reconnaissance, geophysical and mineral surveys, hydrographic charting, determination of boundaries, and pipeline and cable laying surveys. These activities are characterized by flexibility in scheduling and the need for relatively calm seas. Both real-time environmental data, and regional and local weather forecasting data are required.

Exploration activities have by far the most stringent requirements for logistical data. These activities require highly accurate navigation systems that can provide, on a global basis, continuous position updating information with a good repeatability so that operational vessels can return accurately to previous operations or discoveries, or to within proper boundaries. The largest civilian user of high precision navigation systems is the geophysical exploration industry. Exploration activities also require a data transfer capability (teletype messages, facsimile, etc.) that will allow geophysical and surveying operations to communicate program changes and satellite weather pictures from their base to their ships. This provides improved operational efficiency and

maximum profit margins by minimizing the errors that occur in present complicated methods of data relay.

### Production/Operations

Production/operations activities include the use of various types of facilities such as fixed platforms, mobile rigs (drill ships, semisubmersibles, barges, etc.), mining ships, salvage equipment, fishing vessels, and ocean dumping barges.

Many years of data may be required to characterize environmental extremes for design purposes. There are long-range trends in storm size and frequency of occurrence. For example, since 1960 severe hurricanes occur about twice as often in the Gulf of Mexico as they did from 1920 to 1960. Conversely, the U.S. East Coast, which was ravaged by hurricanes in the 1950's, remains relatively free of them in the first part of the period 1960-2000. In another area, recent records show that the number of icebergs drifting south of the 48th parallel has varied between zero and 1200 per year since 1900.<sup>1</sup> Similarly, the edge of the polar pack ice may recede as much as 300 miles, or as little as 20 miles in a given year.<sup>2</sup>

The effect of directionality of winds and waves is also an important design consideration. Such information can be obtained through studies and modeling of several years of data for a given area of the world. The reinforcement of wind, wave and tidal stresses can have a very significant impact on design.<sup>1</sup>

To minimize design uncertainty in ocean mining requires accurate and reliable historical environmental data. Present designs are conservative because of the lack of statistical data on ocean conditions in areas of present interest.

In northern latitudes, information on air and water temperatures is needed to predict icing on structures. When driven by currents and winds, ice flows and rafts could cause high dynamic loads on offshore structures. Monitoring of ice dynamics during freezeup, including growth and progression of the fast ice and the southerly migration of the polar pack, is important in assessing the pileup that may be generated around fixed platforms. Furthermore, historical data on ice are not only helpful in platform design criteria but are essential in operations planning.

Almost without exception, ocean operations require accurate short-term and long-range regional and local weather forecasting, prediction of large storms, and a storm tracking capability. "Waiting